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AF MANUAL 52-22

instructor's guide

ADVANCED ELECTRONIC CIRCUITS

AN/GSQ-T2 TRAINER

DEPARTMENT OF THE AIR FORCE

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DEPARTMENT OF THE AIR FORCE

AIR FORCE MANUAL
NUMBER 52-22

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FOREWORD

This manual is published for the information and guidance of instructor personnel using the AN/GSQ-T2 Electronic Circuit Trainer as a training aid in teaching advanced electronic circuitry.

The first half of this manual consists of classroom lesson plans and suggested examinations for teaching basic circuits. The last half provides a laboratory plan and a completed experiment for each basic circuit panel and a number of panel combinations in the AN/GSQ-T2 Electronic Circuit Trainer.

You are invited to send suggestions, comments and/or recommendations for the improvement of this manual to the Director of Personnel Procurement and Training, DCS/P, Headquarters USAF, Washington 25, D. C.

BY ORDER OF THE SECRETARY OF THE AIR FORCE:

N. F. TWINING
Chief of Staff, United States Air Force

OFFICIAL:

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*Commanders will requisition additional copies of this manual for issue to individuals as required in the performance of training in conjunction with the AN/GSQ-T2 Electronic Circuit Trainer.

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HOW TO USE THIS MANUAL

This manual is designed to aid you, the instructor, in the preparation and presentation of your classroom and laboratory lessons. The first half of the manual consists of lesson plans and examinations. Each lesson plan provides a detailed outline of the subject material to be covered in the classroom and is subdivided as follows:

SUBJECT

A statement of the subject to be covered.

OBJECTIVE

A definition of the scope of the lecture.

MATERIAL REQUIRED

A detailed list of the equipment required to conduct any demonstrations recommended.

INTRODUCTION

A short statement intended to aid in motivating the students. It is meant to show the importance of the subject to be covered and how it ties in with other lessons, demonstrations, and experiments of the course.

SUBJECT MATERIAL

A step-by-step outline of the topics to be covered in the lesson. Drawings, diagrams, and schematics that are suitable for blackboard use are included. Be sure to apportion the time of each lesson among the various topics according to their relative importance.

CONCLUSIONS

A keynote sentence around which a summary of the lesson can be built. Be sure to recapitulate important points made during the lesson and to stress the importance of the subject to the entire course.

ORAL QUIZ

Frequently, questions will be listed here. At times you will have to make up your own. These questions are used to review the lesson and to increase the student's understanding.

Examinations are interspersed among the lesson plans in proper relation to the lessons. They consist of multiple choice, and essay questions as well as mathematical problems. These are useful in testing the student's understanding of a portion of the course. Answers to all of the questions are included in this manual. Use these questions for making up your examinations and to serve as models for making up new questions.

The last half of the manual provides a complete series of laboratory plans and experiments. The laboratory plans are detailed procedures for conducting the laboratory class. The experiments give complete instructions for performing experimental investigations. The students, under the guidance of the instructor, will perform most of the experiments. In some instances, the complexity of the material makes it advisable for the instructor to perform the experiment in the form of a demonstration.

Each laboratory plan is subdivided in the same manner as the lesson plans as follows: SUBJECT, OBJECTIVE, MATERIAL REQUIRED, INTRODUCTION, SUBJECT MATERIAL, and CONCLUSIONS.

Each experiment is subdivided as follows: SUBJECT, OBJECTIVE, MATERIAL REQUIRED, INSTRUCTIONS, PROCEDURE, and CONCLUSIONS. The INSTRUCTIONS consist of warnings, cautions, and other instructions relating to the experiment. When the experiment is to be performed as a demonstration by the instructor, the INSTRUCTIONS inform the student of the part he is to take. The PROCEDURE is a complete step-by-step set of directions for performing the experiment. The CONCLUSIONS are a set of questions at the end of each experiment which serve to summarize the results. Answers to the question are given in this manual.

In some instances, information sheets are included with the experiments. These provide helpful information and recommended trouble-shooting procedures. Supplementary work sheets which contain problems to be solved by the student are included in some experiments.

CONTENTS

Lesson Plans and Examinations

Lesson Plan Title Page

1 Introduction to the Concepts and Circuits Associated with Electronic Systems........................ 1
2 Non-sinusoidal Waves.................... 2
3 RC and RL Phase-shifter Circuits........... 4
4 Feedback Amplifiers, Tuned-plate, Tuned-grid Oscillator, and Push-pull Oscillator...................... 5
Examination No. 1..................... 9
5 RC and Wein-bridge Oscillators........... 12
6 RC Time Constants (Differentiation)....... 15
7 RC Time Constants (Integration).......... 18
8 LR Time Constants (Differentiation and Integration)........................... 20
Examination No. 2..................... 22
9 Series and Parallel Diode Limiters......... 25
10 Triode and Pentode Limiters............. 28
11 Peaking Circuits.......................... 31
12 Wave-shaping Circuits.................... 33
Examination No. 3..................... 35
13 Clamping Circuits........................ 39
14 Introduction to Square-wave Generators; the Eccles-Jordan Trigger Circuit.......... 42
15 One-shot Multivibrator and Cathode-coupled Multivibrator Circuits............. 44
16 Plate-coupled Multivibrator; Synchronization of Multivibrators; Electron-coupled Multivibrator.................... 47
Examination No. 4..................... 49
17 Phantastrons.............................. 52
18 Self-pulsing Blocking Oscillators........... 54
19 Shock-excited Oscillators................. 57
20 Single-swing Blocking Oscillator.......... 59
Examination No. 5..................... 61
21 Counting Circuits........................ 64
22 Characteristics of Neon Tubes and Thyratrons; Introduction to Sawtooth Generators; the Neon Sawtooth Generator.. 66
23 Thyratron Sawtooth Generators; Synchronization......................... 69
24 Vacuum-tube Sawtooth Generators; Trapezoidal Waveform Generators......... 72
25 Bootstrap Sweep Generator Circuit and Expanded Sweep Generators.............. 74
Examination No. 6..................... 76

Lesson Plan Title Page

26 Video Amplifier, Cathode Follower, and Phase Inverter.......................... 80
27 The Cathode-ray Tube..................... 85
28 The Cathode-ray Oscilloscope............ 88
29 Oscilloscope Circuits..................... 90
30 Oscilloscope Vertical Amplifiers and Power Supply............................ 92
Examination No. 7..................... 96
31 The Electromagnetic Cathode-ray Tube..... 99
32 Security..................................100
33 History of Radar.........................102
34 Echo-ranging Principles..................103
Homework Sheet No. 1.................105
35 Typical Radar Systems...................107
Homework Sheet No. 2.................110
36 Radar System Constants..................111
Homework Sheet No. 3.................113
37 General Analysis of Radar System Chains...118
Homework Sheet No. 4.................120
38 Timer Systems...........................125
Homework Sheet No. 5.................130
Examination No. 8.....................135
39 The "A" Scope Indicator.................138
Homework Sheet No. 6.................140

Laboratory Plans and Experiments

Number Title Page

1 Square-Wave Generator....................143
2 The Sawtooth Generator...................151
3 The R-C Oscillator.......................157
4 The Cathode Follower.....................160
5 The Bias Supply..........................164
6 The Mixer................................168
7 The Differentiator Circuit................173
8 The Integrator Circuit....................178
9 Testing the Series Diode Limiter...........183
10 Testing the Parallel Diode Limiter.........186
11 The Series Diode Limiter.................189
12 The Parallel Diode Limiter................195
13 The Triode Limiter.......................202
14 Analysis of a Wave-Shaping Chain.........212
15 Troubleshooting a Wave-Shaping Chain....216
16 The Diode Clamper.......................220
17 The Eccles-Jordan Trigger Circuit.........225

CONTENTS—Continued

Number Title Page

18 The Single-Swing Blocking Oscillator......231
19 The Plate-Coupled Multivibrator...........234
20 The One-Shot Multivibrator................239
21 The Phantastron Circuit...................244
22 The Self-Pulsing Blocking Oscillator.......249
23 The Shock-Excited Peaking Oscillator......255
24 The Shock-Excited Ringing Oscillator......260
25 The Single-Swing Blocking Oscillator......266
26 The Step Counter..........................272
27 The Thyratron Sawtooth Generator........279
28 The Neon Bulb Sawtooth Generator........284
29 The Vacuum-Tube Sawtooth Generator.....288
30 Testing the Voltage Tripler................293
31 Testing the Basic Oscilloscope.............297
32 Troubleshooting the Basic Oscilloscope....302

Number Title Page

33 Special Oscilloscope Circuits—Blanking and Intensifying...........................305
34 Construction and Analysis of a Simplified Radar System..............................310
35 Troubleshooting a Basic Radar System.....319
36 The Multivibrator Timer..................325
37 The Blocking Oscillator Timer............333
38 The "A" Scope Sweep Chain...............341
39 Troubleshooting the "A" Scope Sweep Chain..............................348
40 The Range-Marker Chain..................353
41 Troubleshooting the Range-Marker Chain.................................358
42 The Range-Notch Chain...................363
43 An Advanced Radar System................370
44 Troubleshooting the Advanced Radar System...................................378

LESSON PLAN No. 1

SUBJECT

Introduction to the concepts and circuits associated with electronic systems.

OBJECTIVE

To show the over-all picture of the requirements and objectives of modern radar systems, and to indicate the applications of the various circuits in the accomplishment of the radar function.

INTRODUCTION

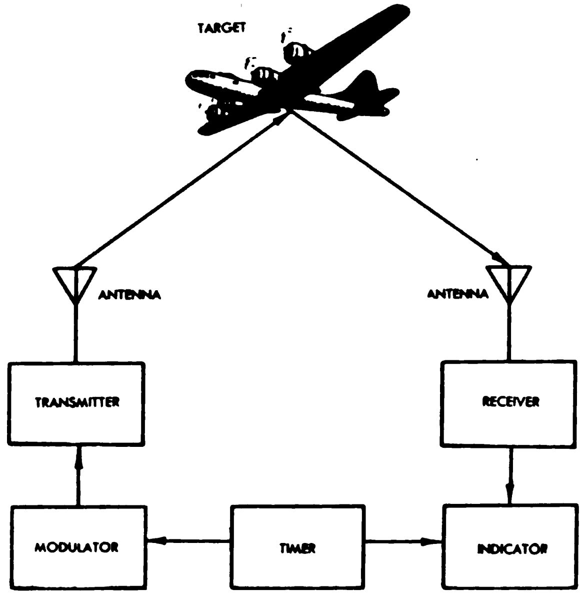
In order to provide a background for the material to be covered in this phase of the course, it is felt that a picture should be created to generate class interest, and to make it possible for the student to realize where special circuits find application. Certain system block diagrams are presented herein to facilitate the teaching of this lesson.

SUBJECT MATERIAL

1. Explain the principles upon which radar is based. Define the term "radar" as a contraction of "radio detection and ranging."
2. Give a brief description of the functions and capabilities of radar systems.
    a. Give some of the uses made of radar during the last World War.
        (1) Search.
        (2) Fire control and gun laying.
        (3) Bombing.
        (4) IFF.
    b. Describe some peacetime (commercial) applications of radar equipments.
        (1) Search.
        (2) Navigation.
        (3) Aircraft blind-landing aids.
    c. Tell of other electronic devices, such as the electronic computers, or "electronic brains," currently used.
    d. Describe, in general terms, the principles of television.
3. Draw a block diagram of a typical radar equipment.
    a. Explain the general functioning of each block.
    b. Show how the individual blocks are correlated into a practical functioning system.
    c. Show and name various waveforms likely to be encountered in each of the blocks. Explain why each of these unusual waveforms are necessary to the proper functioning of the radar system.
4. Explain the use of and need for remote-control devices, such as relays, synchros, etc., to increase the versatility of electronic systems.
    a. Make use of a simple block-diagram representation of such control systems. Again, be careful to keep these descriptions in general terms only.
5. Explain that the following set of LESSON PLANS will present the theory of operation and show detailed applications of circuits capable of generating, amplifying, modifying, and relaying or transmitting the special waveforms and signals associated with radar systems.

CONCLUSIONS

Radar, a vast new field of study, has made it possible for man to successfully "see" through darkness, fog, or clouds. The complexity of radar and other electronic systems is greatly reduced through an understanding of their fundamental requirements and objectives. This lesson is intended to present such information, and also to describe some of the special wave shapes necessary in practical electronic systems.



Elements in Pulse Radar System

ORAL QUIZ

1. What does the name radar stand for?
2. What are the requirements of a radar system?

LESSON PLAN No. 2

SUBJECT

Non-sinusoidal waves.

OBJECTIVE

To show the composition of nonsinusoidal waveforms encountered in radar systems.

INTRODUCTION

Pure sine waves are basic wave shapes. In radar, waves of many different and complex shapes are used, particularly square, saw-tooth, and peaked waves. The composition of these differently shaped waves must be studied, so that the treatment of them in various circuits can be understood.

SUBJECT MATERIAL

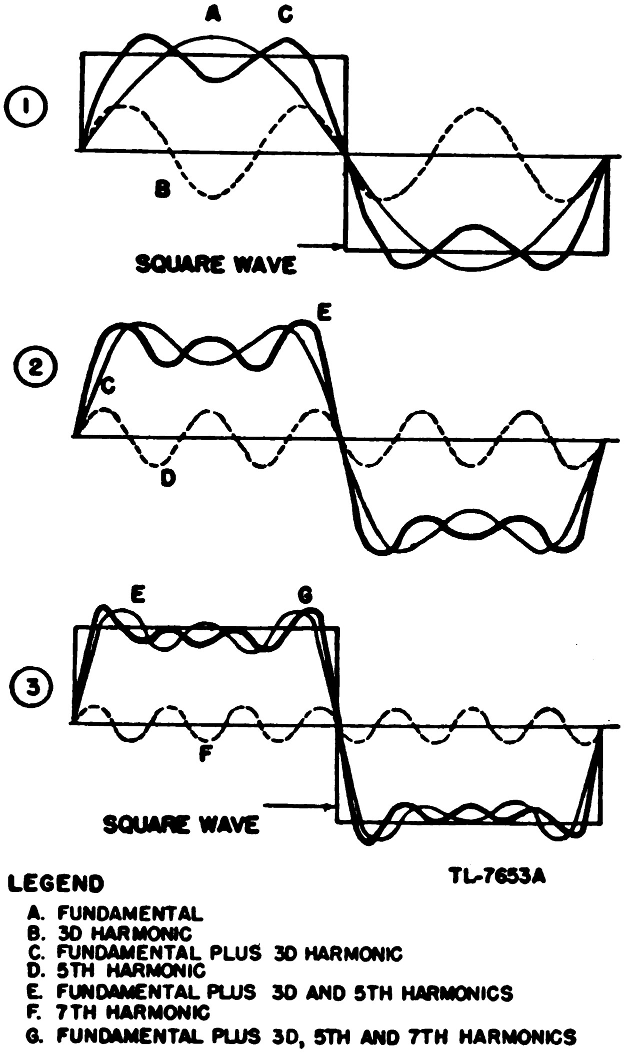
1. Draw, on the blackboard, three cycles of each of the following waveforms and tell the class what they are.
   a. Square wave.
   b. Saw-tooth wave.
   c. Peaked wave.
2. Define the following terms:
   a. Periodic wave.
   b. Harmonics.
   c. Rise time.
   d. Fall or decay time.
   e. Leading edge.
   f. Trailing edge.
3. Develop, step by step, with a blackboard drawing, the composition of a square wave from sinusoidal components.
4. Develop, step by step, with a blackboard drawing, the composition of a saw-tooth wave from sinusoidal components.
5. Develop, step by step, with a blackboard drawing, the composition of a peaked wave from sinusoidal components.
6. Draw, and discuss briefly, waves with unequal alternations.
7. Discuss the circuit requirements for the passing of nonsinusoidal wave shapes through an amplifier.
8. Discuss briefly, the distortion circuits capable of producing the waveforms mentioned above. Indicate that this distortion is to be accomplished by controlling the size of the resistances, capacitances, and inductances of the circuits.

CONCLUSIONS

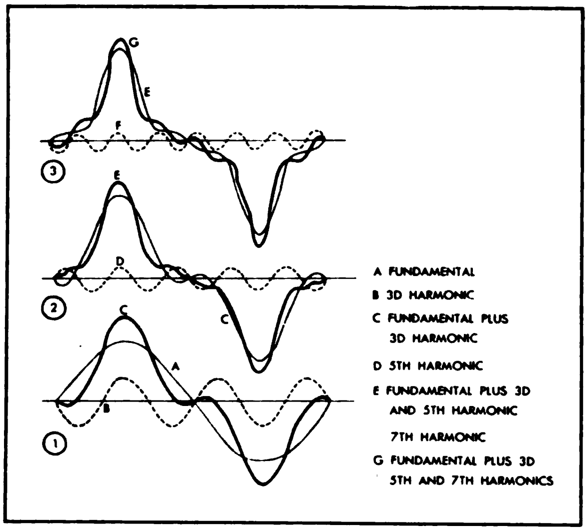
Nonsinusoidal waveforms, frequently encountered in radar systems, can be constructed from basic sine waves. The circuit requirements for passing an undistorted nonsinusoidal wave are a wide, flat frequency response and freedom from phase shifts.

ORAL QUIZ

1. Name three waveforms, other than sinusoidal, which are encountered in radar systems.
2. Define a periodic wave.
3. List the order and phase relation of harmonics in:
   a. A square wave.
   b. A saw-tooth wave.
   c. A peaked wave.
4. What are the circuit requirements for passing a square wave through an amplifier?
5. Define the expression "rise time," as applied to a square wave.
6. Define the term "fall time" or "decay time."


A
C
①
B
SQUARE WAVE
E
②
C
D
E
G
③
F
SQUARE WAVE
TL-7653A
LEGEND
A. FUNDAMENTAL
B. 3D HARMONIC
C. FUNDAMENTAL PLUS 3D HARMONIC
D. 5TH HARMONIC
E. FUNDAMENTAL PLUS 3D AND 5TH HARMONICS
F. 7TH HARMONIC
G. FUNDAMENTAL PLUS 3D, 5TH AND 7TH HARMONICS

Composition of a square wave


G
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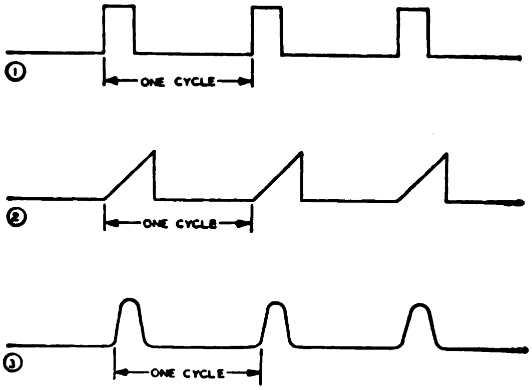
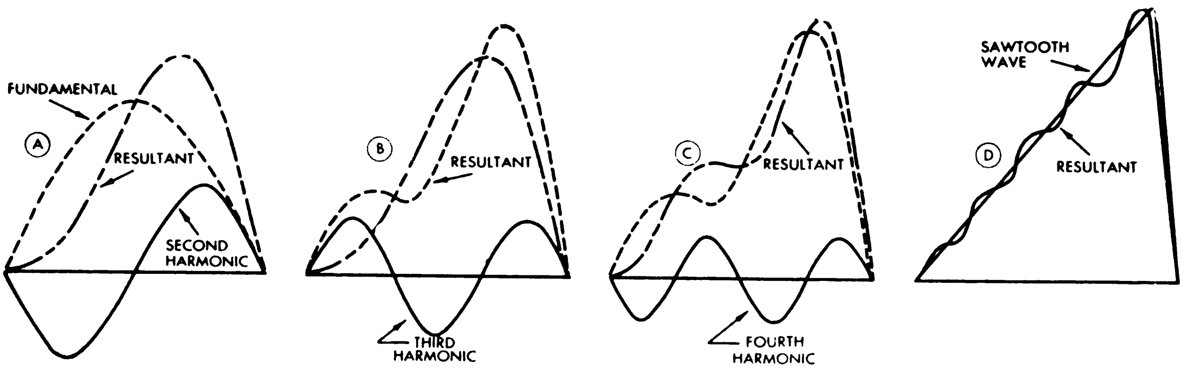
A FUNDAMENTAL
B 3D HARMONIC
C FUNDAMENTAL PLUS 3D HARMONIC
D 5TH HARMONIC
E FUNDAMENTAL PLUS 3D AND 5TH HARMONIC
7TH HARMONIC
G FUNDAMENTAL PLUS 3D 5TH AND 7TH HARMONICS

Composition of Peaked Wave



Waves with unequal alternations



Composition of Sawtooth Wave

LESSON PLAN No. 3

SUBJECT

R-C and R-L phase-shifter circuits.

OBJECTIVE

To demonstrate the methods and waveforms used to produce phase shifting of sinusoidal waves.

INTRODUCTION

Phase shifting has many applications in radio and radar. Outputs taken from circuits such as those to be discussed will be used to produce circular time bases, variable delays, etc.

SUBJECT MATERIAL

1. Briefly review the following points on phase relationships:

a. The current and voltage are in phase in a resistor connected in an a-c circuit.

b. The current leads the voltage by 90° in a capacitor connected in an a-c circuit.

c. The current lags the voltage by 90° in an inductor connected in an a-c circuit.

d. When a resistor and a capacitor are connected in series in an a-c circuit, the voltage across the resistor leads the voltage across the capacitor by 90°.

e. When a resistor and an inductor are connected in series in an a-c circuit, the voltage across the resistor lags the voltage across the inductor by 90°.

2. Show that changing the size of R, C, or L, or even the frequency of the input sine wave in the examples of paragraph 1, above, has no effect on the phase shift, only the relative amplitudes of the two output voltages are changed.

3. Explain the R-C phase-shifting network.

a. Work a problem with vectors where $R = 10X_c$.

b. Work a problem with vectors where $R = X_c$.

c. Work a problem with vectors where $R = 1/10X_c$.

d. Work a problem showing the effects of increasing and decreasing the frequency of the voltage applied to a fixed circuit.

4. Discuss the R-L phase-shifting circuits, giving problems similar to those used to cover the R-C phase-shifting circuit.

5. Draw, on the blackboard, a phase-shifting network continuously variable over 360°, using a phase-shifting capacitor circuit. Explain the operation of the circuit.

CONCLUSIONS

Simple R-C and R-L circuits can be employed to obtain a shift of the phase in a circuit.

ORAL QUIZ

1. In a circuit where $X_c = R$, what is the phase relationship between E_{app} and E_r?

2. What is the phase relationship between F_c and E_{app}?

3. In a circuit where $R = 10\ X_c$, what is the phase relationship between E_{app} and E_l?

4. What is the phase relationship between E_r and E_l?

5. What is the phase relationship between E_{app} and E_r?

LESSON PLAN No. 4

SUBJECT

Feedback amplifiers, tuned-plate, tuned-grid oscillator, and push-pull oscillator.

OBJECTIVE

To review the development of oscillators, and to teach the theory of operation of the tuned-plate, tuned-grid and push-pull oscillators.

INTRODUCTION

The feedback principle is employed in many circuits. Negative, or degenerative, feedback is used to improve stability and wave shape; positive, or regenerative, feedback can be made to produce oscillations in a circuit.

SUBJECT MATERIAL

1. Discuss feedback amplifiers.

a. Explain the term "regenerative feedback," and describe its application to oscillators.

b. Explain the term "degenerative feedback," and show its application in circuits.

c. Through the use of the gain formula ($\text{Gain} = \frac{A}{1-\beta A}$), show when feedback is regenerative or degenerative.

2. List the advantages and disadvantages of degenerative feedback.

a. Explain several methods of obtaining degenerative feedback.

b. Draw and explain degenerative feedback circuits. Figure 1, Figure 2.

3. Draw and describe the cathode-follower circuit. Figure 3.

a. Show an equivalent circuit of a cathode follower. Fig. 4.

b. Discuss the input and output impedances.

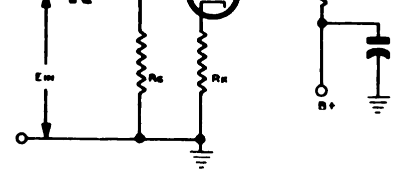
c. Discuss the voltage gain.

d. Discuss the power gain.

e. Discuss frequency considerations.

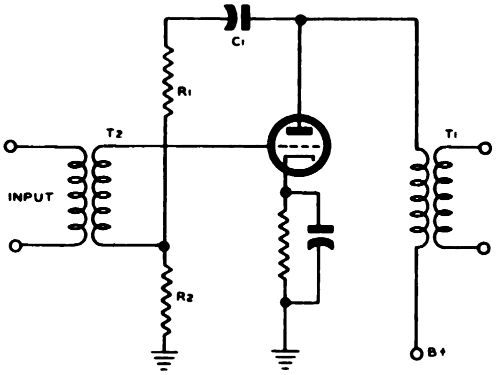
4. Show the action of a basic oscillator circuit. Fig. 5.

a. Discuss the fact that the feedback network produces the required phase reversal of the voltage coupled back to the grid circuit from the plate circuit.



CURRENT FEEDBACK IS OBTAINED THROUGH THE RESISTOR RK

Figure 1



VOLTAGE FEEDBACK IS GAINED THROUGH RESISTOR R2

Figure 2

Equivalent Circuit of a Cathode Follower

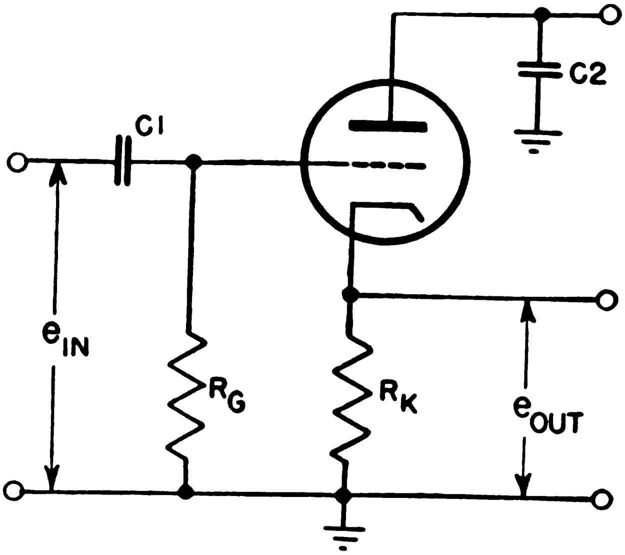


Figure 3

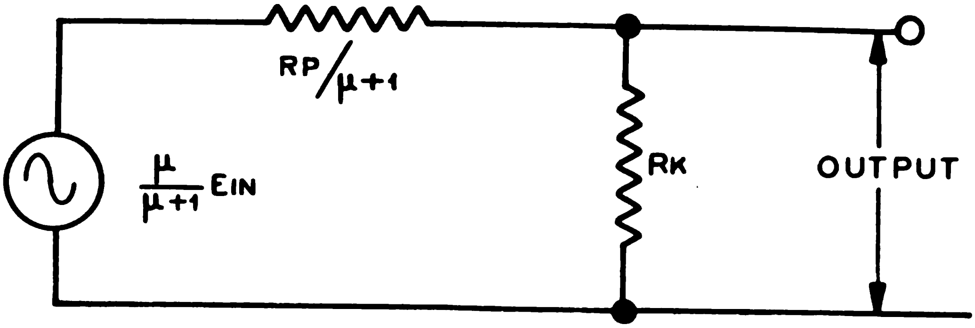


Figure 4

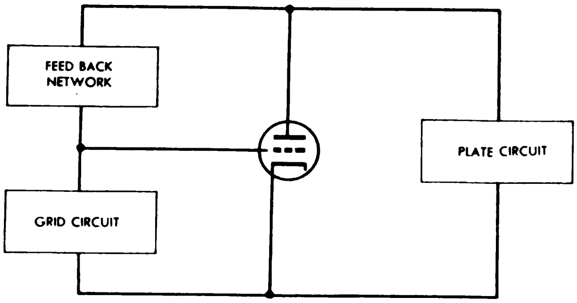


Figure 5

5. Briefly review the flywheel action of a parallel L-C tank circuit.

6. Discuss the operation of the tuned-plate, tuned-grid oscillator. Use an equivalent circuit to facilitate the expansion of this circuit. Figure 6, Figure 7.

a. Discuss briefly the characteristics of a quarter-wavelength shorted stub with regard to its use in an oscillator at higher frequencies.

b. Substitute the stub for the L-C tank circuit in the tuned-plate, tuned-grid oscillator, and explain its theory of operation.

7. Explain the theory of operation of the push-pull oscillator circuit. Figure 8.

a. Explain the reason for the use of two tubes.

b. Substitute the quarter-wave stubs (Lecher lines) for the tank circuits in the plate and grid circuits.

c. Explain the operation of the circuit using the quarter-wave lines for tank circuits.

8. Show how energy may be coupled out of these oscillators.

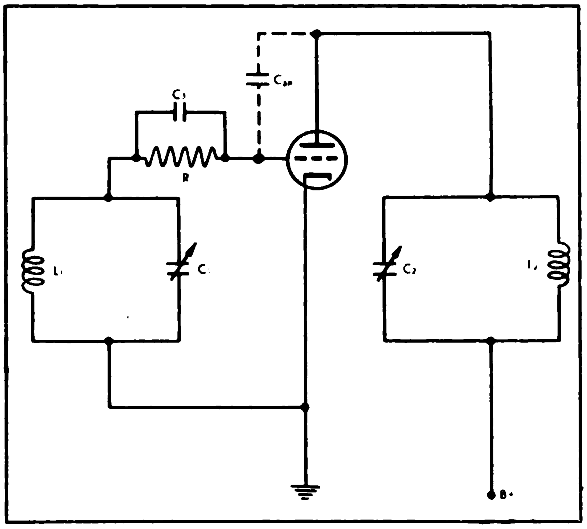


Figure 6

CONCLUSIONS

The principle of feedback has many applications in radio and radar. There are definite advantages and disadvantages in both degeneration and regeneration. The cathode follower and the oscillator are classic examples of both types of feedback.

ORAL QUIZ

1. Discuss the advantages and disadvantages of the cathode-follower circuit.

2. Explain how feedback is obtained in the tuned-plate, tuned-grid oscillator.

3. Explain the feedback phase relations necessary for degeneration and regeneration.

4. Give the advantages of a quarter-wavelength shorted stub as a substitute for a tank circuit for higher frequencies.

5. Explain the operation of the push-pull oscillator circuit.

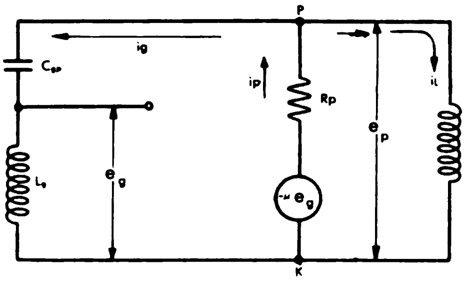


Figure 7

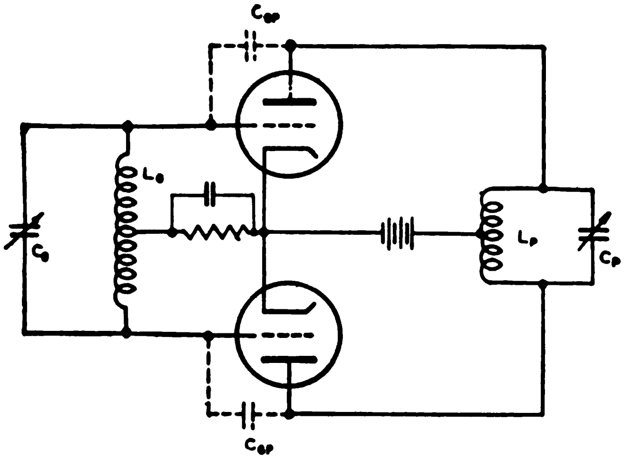


Figure 8

SECTION________________

ADVANCED ELECTRONIC CONCEPTS AND CIRCUITS

EXAMINATION No. 1

NAME______________________________ **GRADE**______________________________

DATE______________________________ **TIME ALLOTTED**______________________________

INSTRUCTIONS

1. Do not raise this cover page until told to do so by the instructor.
2. If you need help with any particular question, raise your hand, and the instructor will come to you.
3. Peform any necessary calculations on the examination sheet.
4. Make sure that your name, section, and the date are entered in the spaces provided.
5. REFERENCE TEXTS OR NOTEBOOKS MAY NOT BE USED FOR THIS EXAMINATION.

SAMPLE

COVER

PAGE

EXAMINATION No. 1

1. _a_. A saw-tooth wave contains:
   a. Even and odd order harmonics.
   b. Only even order harmonics.
   c. Only odd order harmonics.
   d. Odd order harmonics out of phase.

2. _b_. If the number of in-phase odd order harmonics in a non-sinusoidal wave is increased, the:
   a. Peaks will be narrower and of greater amplitude.
   b. Leading edge will be steeper.
   c. Leading edge will rise less rapidly.
   d. Saw-tooth wave will rise and fall more rapidly.

3. _b_. Radar circuits must pass non-sinusoidal waves with a minimum of distortion. This requires that the circuits have:
   a. Very good low-frequency response.
   b. Wide frequency response and no phase shift.
   c. A great amount of degeneration.
   d. Very high operating voltages.

4. _c_. If the resistance in a series R-C circuit is increased, the current through the resistor will:
   a. Be more in phase with the current through the capacitor.
   b. Lead the voltage across the capacitor by a greater amount.
   c. Be more in phase with the applied voltage.
   d. Be more in phase with the voltage across the resistor.

5. _b_. In a series R-L circuit, the voltage across the coil will always be:
   a. 90° out of phase with the applied voltage.
   b. 90° out of phase with the current through the resistor.
   c. In phase with the applied voltage.
   d. In phase with the voltage across the resistor.

6. _d_. If the capacitance is increased in a series R-C circuit, the voltage drop across the capacitor will:
   a. Be more in phase with the current through the capacitor.
   b. Be more in phase with the applied voltage.
   c. Increase.
   d. Decrease.

7. _c_. If the frequency of the voltage applied to a series R-L circuit is increased, the voltage drop across the resistor will:
   a. Remain the same.
   b. Be more in phase with the applied voltage.
   c. Lag the applied voltage by a greater phase angle.
   d. Lead the current through the coil by a greater phase angle.

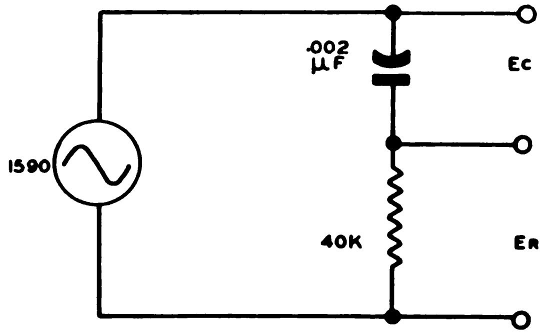


Figure 1

8. Refer to figure 1, and calculate Z_t.

Solution:

$$Z_t = \sqrt{R^2+X^2}$$
$$= \sqrt{16\times 10^8+25\times 10^8}$$
$$= \sqrt{41\times 10^8}$$
$$Z_t = 64{,}000 \text{ ohms.}$$

9. Refer to figure 1, and calculate the voltage drop across R.

Solution:

$$E_R = IR$$
$$I = \frac{E_T}{Z}$$
$$= \frac{100}{64{,}000}$$
$$= 1.563\times 10^{-3}$$
$$I_R = 1.563\times 10^{-3}\times 40{,}000$$
$$E_R = 62.5 \text{ volts.}$$

10. Referring to figure 1, determine the phase relation between E_R and E applied, and indicate whether E_R is leading or lagging E applied.

Solution:

$$\tan\theta = \frac{X}{R}, \text{ where } \theta = \text{phase angle}$$

$$\text{and } X = \frac{.159}{fc}$$

$$X = \frac{.159}{1590 \times .002 \times 10^{-6}}$$

$$X = 50{,}000 \text{ ohms}$$

$$\tan\theta = \frac{50{,}000}{40{,}000}$$

$$= 1.25$$

$$\theta = \text{arc tan } 1.25$$

$$\theta = 51.35^\circ \text{ leading.}$$

11. Referring to figure 2, is it possible to obtain an output that is exactly 90° out of phase with E applied? Why?

For 90° phase shift, R would have to be zero; hence, no output would be available.

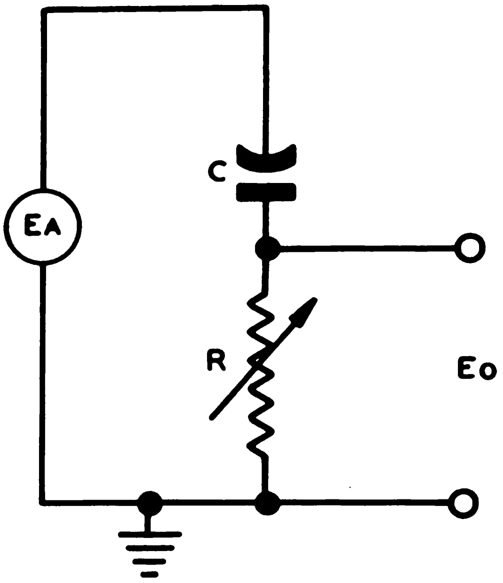


Figure 2

12. c . Feedback is obtained in a cathode follower through:

a. The grid-to-plate capacitance.

b. A capacitor connected from plate to ground.

c. The unby-passed cathode resistor.

d. No feedback is employed in cathode followers.

13. c . The voltage gain of a cathode follower:

a. May be made as high as the amplification factor of the tube.

b. May be made as high as ¾ of the μ (mu) of the tube.

c. Is always less than unity.

d. None of the above is correct. It has zero voltage gain.

14. c . Negative feedback is used in amplifiers to:

a. Increase the gain.

b. Reduce the interelectrode capacitance.

c. Reduce distortion.

d. None of the above is correct.

15. A cathode follower may be considered as a generator producing an output voltage of $\mu(e_g - e_k)$ with an internal resistance r_p: Calculate the current through, and the voltage across, the cathode resistor if a signal of 10 volts amplitude is fed to the grid of the cathode follower. The tube has a μ of 20, and r_p of 7.5k. The cathode resistor is 2k. Note that $e_k = IR_K$. Use any formula you know that applies, in addition to the above.

Solution:

$$\text{Gain (A)} = \frac{\mu R_k}{r_p + R_k(\mu + 1)}$$

$$= \frac{20 \times 2k}{7.5K + 2k\ (21)}$$

$$= \frac{40k}{49.5K}$$

$$= .808$$

$$e_k = IR_k$$

$$\text{Therefore, } I = \frac{e_k}{R_k} \qquad e_k = e_g A = .808 \times 10 = 8.08v$$

$$= \frac{8.08}{2k}$$

$$= 4.04 \text{ ma.}$$

16. b. Which of the following indicates the proper phase relationship of the feedback voltage, with respect to the plate voltage, of an oscillator?

a. 90° out of phase at the grid.

b. 180° out of phase.

c. In phase.

d. Leading only slightly (as in an inductive tank circuit).

e. None of the above is correct.

17. b. The frequency of the phase-shift oscillator may be increased by:

a. Increasing the resistance or capacitance of the circuit.

b. Decreasing the resistance or capacitance of the circuit.

c. Increasing the inductance of the tank circuit.

d. Increasing the capacitance of the L-C tank.

e. None of the above is correct. There is no such oscillator circuit.

18. d. In an oscillator, the energy fed to the grid comes from:

a. There is no energy fed to the grid; the grid supplies power.

b. The low-voltage terminal of the power supply.

c. The grid bias supply.

d. The plate circuit of the tube.

19. d. In a tuned-plate, tuned-grid oscillator:

a. The plate circuit only is tuned capacitively.

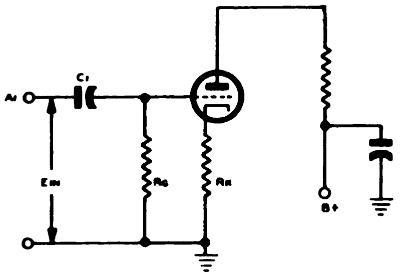
b. The plate and grid circuits are both tuned on the capacitive side of resonance.

c. Only the plate circuit is tuned slightly above resonance.

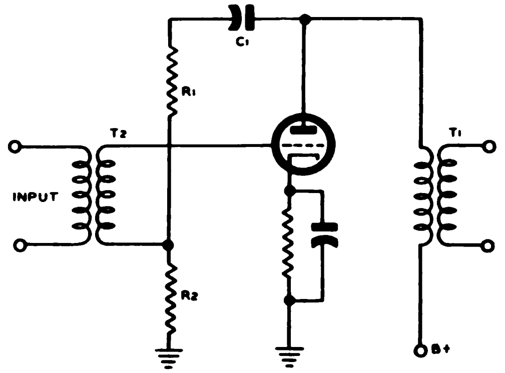
d. The plate and grid tanks are both tuned slightly above the oscillator frequency.

e. The plate and grid circuits are both tuned slightly below the oscillator frequency.

20. Draw two circuits which show two methods of obtaining degenerative feedback.



CURRENT FEEDBACK IS OBTAINED THROUGH THE RESISTOR RK



VOLTAGE FEEDBACK IS GAINED THROUGH RESISTOR R2

LESSON PLAN No. 5

SUBJECT

R-C and Wein-bridge oscillators.

OBJECTIVE

To demonstrate to the class the theory and operation of R-C sine wave oscillators.

MATERIAL REQUIRED

1. R-C Oscillator Demonstation Unit.
2. Five-inch cathode-ray oscilloscope.
3. Power supply.
4. Audio signal generator.
5. Vacuum-tube voltmeter.

INTRODUCTION

In an R-C oscillator, the frequency is determined by a resistance-capacitance network that provides regenerative coupling between the output and input of a feedback amplifier. No tank circuit is used to control the frequency.

SUBJECT MATERIAL

1. Set up the demonstration unit equipment, but do not apply power to it.

Give a brief description of the over-all operation of the phase-shift oscillator circuit. (Subsequent steps in this LESSON PLAN are intended to provide detailed theory of operation.)

2. Refer to the demonstration unit diagram, to calculate the following:

a. With the values on the demonstration unit for one L-section, calculate the amount of phase shift at 1200 cycles per second.

b. Calculate the amplitude of the voltage drop across R, if the applied voltage is 50 volts.

3. Apply a 1200-cycle signal to the first L-section of the phase-shift network; and compare the applied signal with the signal across the resistor.

4. Calculate the phase shift in the next section, and the amplitude of the voltage drop across the next resistor.

By means of the demonstration setup, show the class the total phase shift between the input signal and the voltage developed across the second resistor.

5. Explain to the class that the phase shift need not necessarily be 60° per section; also, explain why it is not practical to obtain a 90° shift per section.

a. Now that the total phase shift for two L-sections has been determined, calculate the phase shift remaining to be developed to arrive at 180° shift.

b. When the value of capacitance for each section is similar, calculate the remaining value of resistance to be inserted in the final section of the phase-shift network, to produce a shift of 180°.

c. Adjust the potentiometer of the R-C oscillator until the scope shows the input and output waveforms to be exactly 180° out of phase. Measure the resistance of the potentiometer, and compare it with the calculated value of the resistance.

6. Show with drawings the waveform analysis of the phase-shift circuit.

Explain that while it is possible to produce a 180° phase shift, the feedback voltage is very small; therefore, it is necessary to use a pentode to give sufficient gain to sustain oscillations.

7. Explain methods of frequency control.

a. Discuss changes in the values of R and C.

b. Discuss the effects of changes in bias.

8. Apply power to the R-C Oscillator Demonstration Unit, and show the class the effects of changes in R, C, and bias.

9. Draw the Wein-bridge oscillator circuit, and explain its operation; make use of the frequency feedback voltage curves to facilitate the explanation.

Explain that this circuit will oscillate even without the bridge network, but that, because of the bridge, the circuit will oscillate at only one frequency.

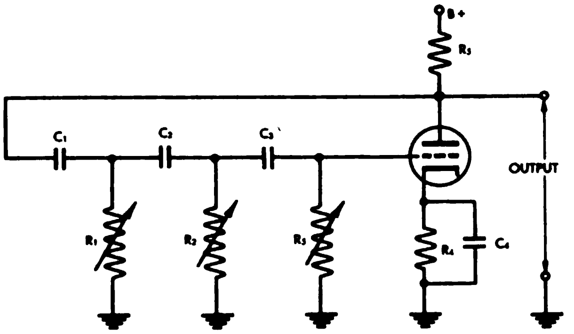
10. Show and explain the phase-shift circuit of the Wein-bridge oscillator.

a. Discuss the degeneration path.

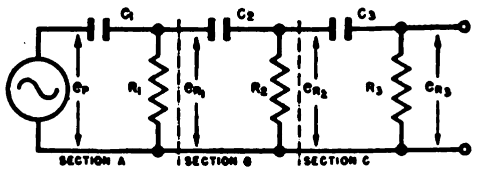
b. Discuss the frequency selective path.

c. Give the formula for the frequency of operation.

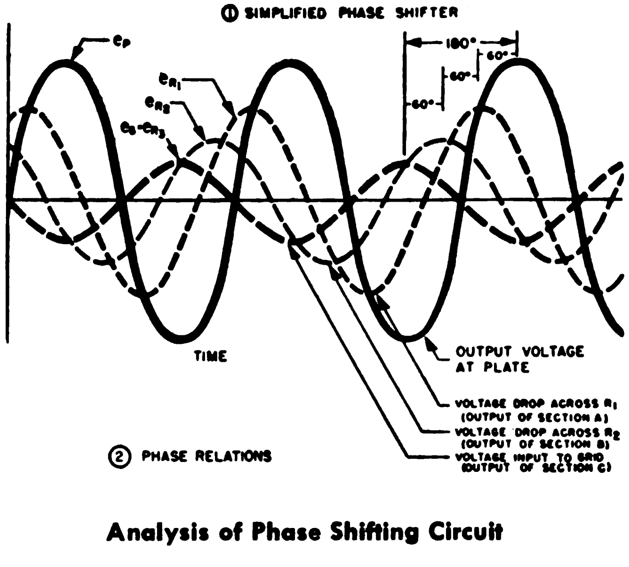
d. Discuss the fact that this oscillator is used where a very stable audio frequency is required.



Phase Shift Oscillator



① SIMPLIFIED PHASE SHIFTER



② PHASE RELATIONS

Analysis of Phase Shifting Circuit

CONCLUSIONS

The R-C type oscillator is used widely as a source of stable audio oscillation. A form of this type of oscillator is used in practically all fine audio signal generators. This circuit is sometimes used as a timing oscillator for radar systems, because of its inherent stability.

ORAL QUIZ

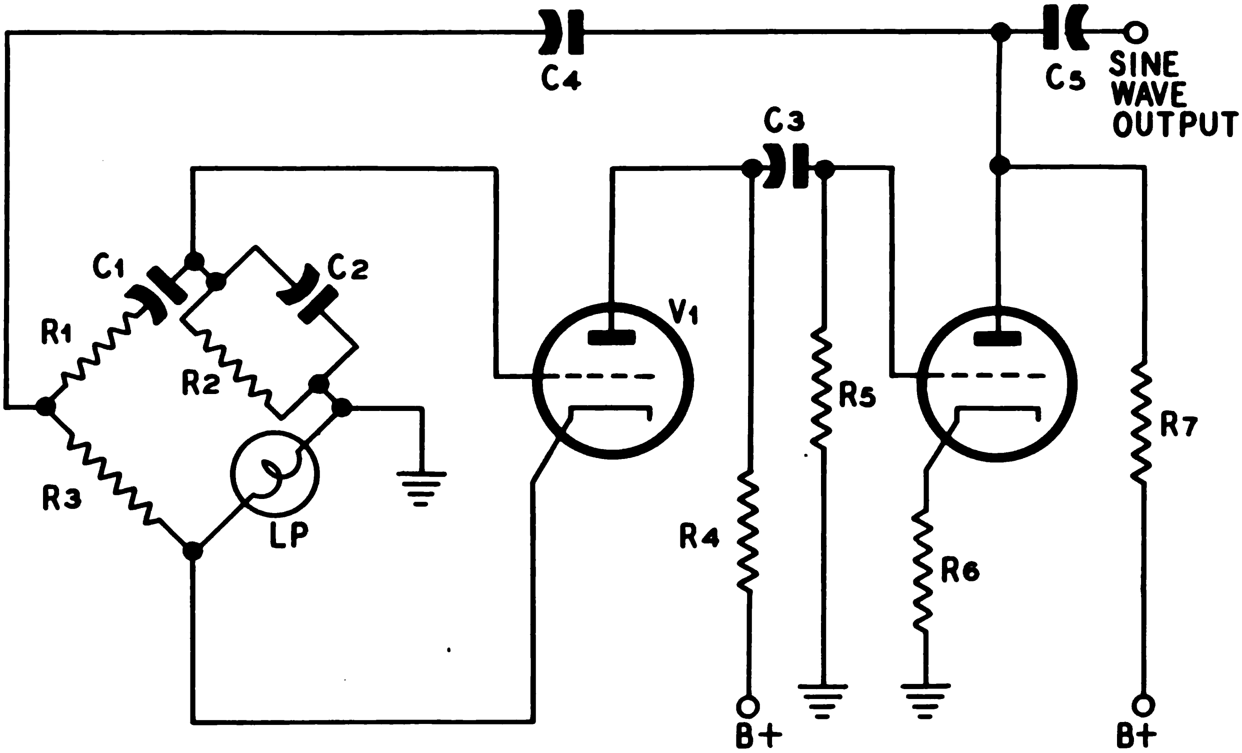
1. Why is it impractical to obtain a phase shift of 90° with only one R-C section?

2. What is the most important feature of a Wein-bridge oscillator?

3. Why is it necessary to use a high-gain tube in the R-C oscillator?

4. Why does the degeneration in a Wein-bridge oscillator tend to remain constant over a wide band of frequencies?

5. It is necessary to have a phase shift of exactly 60° per section in the R-C oscillator?



Wein Bridge Oscillator

LESSON PLAN No. 6

SUBJECT

R-C time constants (differentiation).

OBJECTIVE

To explain the operation and uses of R-C differentiator networks.

MATERIAL REQUIRED

1. R-C Time Constant Demonstration Unit.
2. Five-inch cathode-ray oscilloscope.
3. Vacuum-tube voltmeter.
4. Plate-coupled Multivibrator Demonstration Unit.
5. Power Supply Demonstration Unit.

INTRODUCTION

In radar applications, circuits are sometimes required to pass various wave shapes with a minimum of distortion, or, on the other hand, circuits are sometimes required to effect a specific type and degree of distortion in passing a waveform. R-C differentiator and integrator networks are often employed to perform these functions. This lesson will be devoted to the differentiating process, while integrating is covered in the next lesson.

SUBJECT MATERIAL

1. Explain what is meant by differentiation and integration, as applied to R-C and L-R circuits.

2. Explain R-C charging by showing that a capacitor cannot charge or discharge instantaneously.

Describe the charging action of the R-C circuit, showing the voltage and current waveforms resulting from the application of a d-c voltage.

a. At the instant voltage is applied, $e_c = 0$, $e_r = E_{app}$, I is maximum; therefore, the capacitor appears as a short circuit at the first instant, and the amount of current that flows in the circuit is determined solely by the applied voltage and the value of circuit resistance.

b. As the capacitor charges, the current flow in the circuit decreases, as evidenced by the fact that the voltage drop across the resistor decreases. Show the similarity to a voltage divider, where the sum of the voltages E_r and E_c at all times must equal the applied voltage.

c. The decreasing current flow can be attributed to the fact that, as the capacitor charges, it acts as a source of opposite polarity in series with the applied voltage, thereby reducing the total voltage applied to the resistor, causing the current flow to decrease.

d. When the capacitor becomes fully charged, the voltage across the resistor falls to zero. Actually, no capacitor will fully charge to the applied voltage, because of its leakage.

3. Explain the discharging action of an R-C circuit; restating that a capacitor cannot discharge instantaneously.

Describe this action, using current and voltage waveforms.

a. Show that when the ground end of R1 is connected to the input end of C1 the charged capacitor now acts as the source of voltage, and is tied directly across the resistor. Electrons now leave the negative plate of the capacitor and try to get back to the positive plate through the resistor.

b. At the instant the circuit is closed, E_r is max., I is max.

c. As the capacitor discharges, E_c decreases, I decreases, and E_r maintains the same potential that exists across the capacitor, since it parallels the capacitor.

d. When C becomes fully discharged, the current falls to zero and E_r also becomes zero.

4. Discuss the concept of the R-C time constant.

a. Since a capacitor cannot charge or discharge instantaneously, there are factors which control its charge and discharge.

b. Discuss the formula $T = RC$, showing the class that the capacitor will charge to 63% of the applied voltage in one RC time.

c. Discuss the fact that the capacitor will charge to 63% of the remaining applied voltage in every RC time.

d. Show the class the 2.3 RC and 4.6 RC points of charge. State that, for practical purposes, the capacitor is considered to be fully charged in 5 to 10 RC times.

e. Discuss the percentage fall in voltage across the resistor as the capacitor charges.

5. Develop the universal time constant for an R-C circuit.

6. Set up the R-C Time Constant Demonstration Unit, using the 16-μf. capacitor and a 1.2-megohm resistor.

a. Connect a milliammeter in series with the resistor; then connect the Power Supply Unit to the input of the R-C Time Constant Demonstration Unit.

b. With the vacuum-tube voltmeter (v.t.v.m.), measure the applied voltage; then place the v.t.v.m. across the resistor and make a time check on the charge time of the capacitor by observing the change of voltage indicated by the meter.

c. Take readings of E_r at approximately one-second intervals as the capacitor charges, and develop the R-C curve on the blackboard.

d. After the capacitor has become charged, reverse the v.t.v.m. connections to the resistor; then short the components together and allow the capacitor to discharge through the resistor. Be sure to point out that the polarity of the voltage drop across R is now reversed. Remove the v.t.v.m. from the circuit when the capacitor has discharged.

e. Check the calculated time constant against the measured time.

7. Compare the output waveform of this simple "square-wave generator" with the applied d-c voltage waveform.

a. Show that both waveforms rise rapidly, remain at a fixed level for a period of time, then fall rapidly back to the original level and remain there for a period of time.

8. Explain what is meant by a "long time constant" circuit.

a. Show the voltage and current waveforms obtained from such a circuit when a square wave of voltage is applied to it.

b. Explain that the capacitor does not have time to fully charge, so that the voltage drop across R doesn't fall off very much during the positive half-cycle.

9. Explain what is meant by "medium time constant," and show the relationship between a medium time constant (same duration as a half-cycle of the square wave) and an applied square wave.

a. Explain that the voltage across the capacitor can rise to 63% of the applied voltage, and that the voltage drop across R falls to 37% of the applied voltage in one RC time.

b. Show the current and voltage waveforms obtained from such a circuit when a square wave is applied to it.

10. Explain what is meant by a "short time constant," and show the relationship between a short time constant (one-tenth of the time duration of the square-wave input) and an applied square wave.

a. Develop the positive and negative spikes which appear across the resistor.

b. Explain that the capacitor can charge in a short time to the full applied voltage.

11. Connect the output of the Plate-Coupled Multivibrator Demonstration Unit to the R-C unit, and demonstrate the effects discussed in paragraphs 8, 9, and 10.

12. Discuss the effects of short and long time constants on saw-tooth waveforms.

13. Show that a sine wave cannot be differentiated (or integrated).

14. Describe briefly a number of the types of circuits that make use of these differentiated waves.

CONCLUSIONS

R-C differentiation circuits are employed in many radar applications, notable among which is the generation of sharp trigger pulses. The development of the sharp pulse is accomplished through the use of a very short time constant R-C circuit.

ORAL QUIZ

1. Can a capacitor charge or discharge instantaneously?

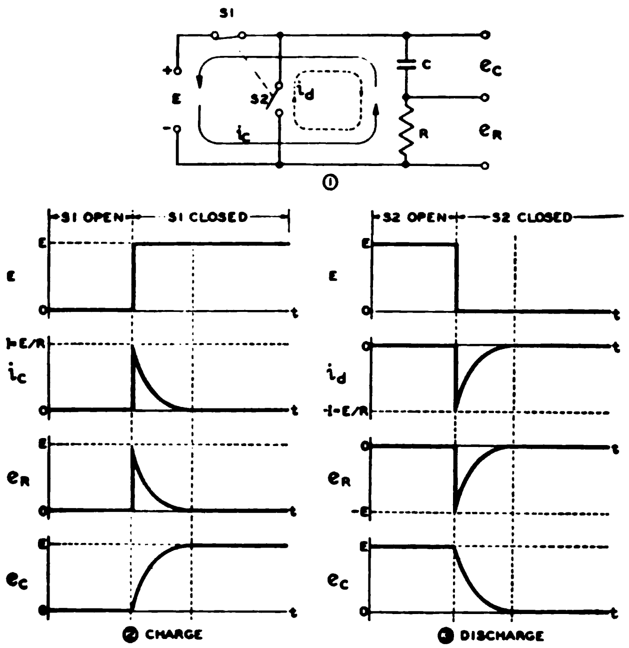
2. To what percentage of the applied voltage will a capacitor charge in one RC time?

3. What is the voltage drop across the resistor at the instant a voltage is applied?

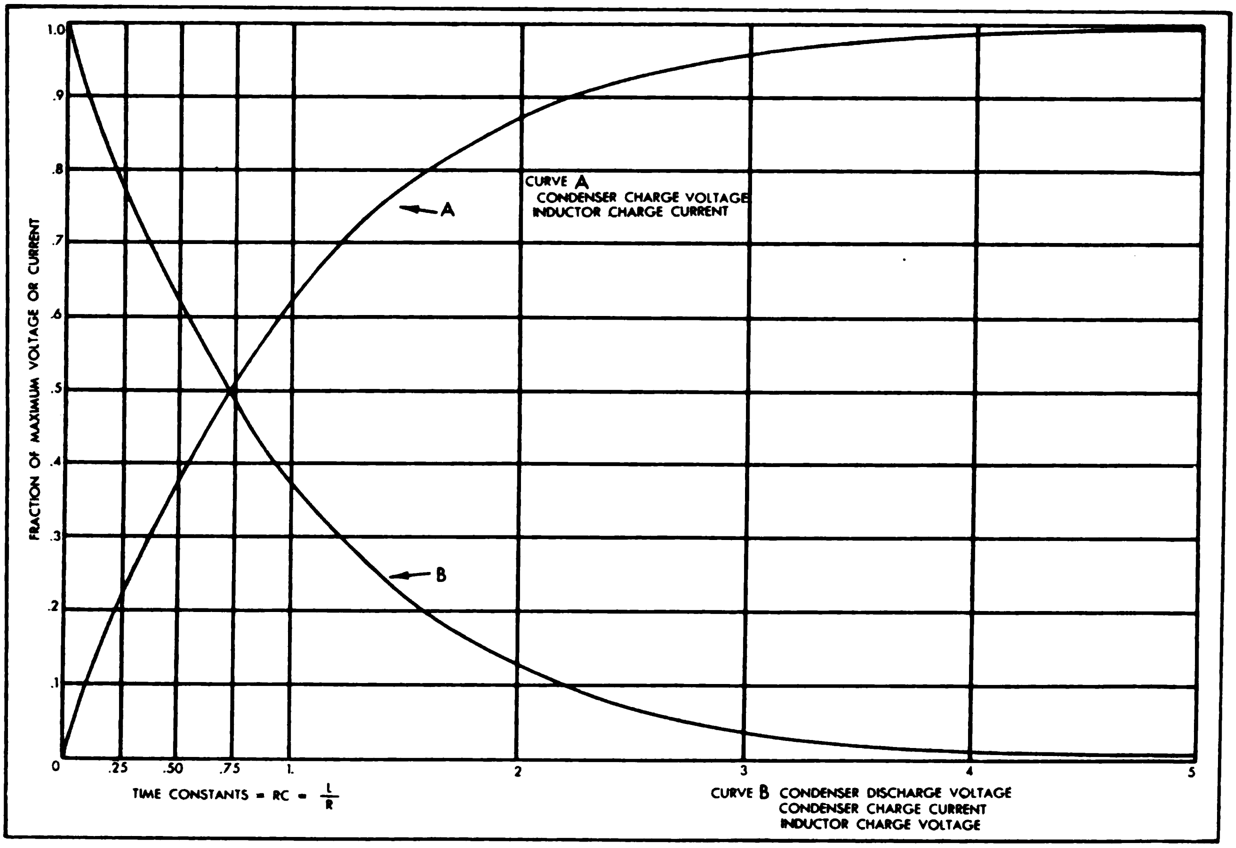
4. If a square wave were applied to a circuit having a short RC time constant, what would the differentiated output wave form look like?

5. When a sine wave is applied to a circuit having a short RC time constant, what does the waveform of the voltage across the resistor look like?

6. Show the output waveform obtained when a saw-tooth voltage is differentiated in a short RC time constant circuit.



Charge and Discharge of an R-C circuit



Universal Time Constant Chart

LESSON PLAN No. 7

SUBJECT

RC time constants (integration).

OBJECTIVE

To familiarize the student with the uses and operation of R-C integrator networks.

MATERIAL REQUIRED

1. R-C Time Constant Demonstration Unit.
2. Five-inch cathode-ray oscilloscope.
3. Vacuum-tube voltmeter.
4. Plate-Coupled Multivibrator Demonstration Unit.
5. Power Supply Demonstration Unit.
6. Thyratron Saw-tooth Generator Demonstration Unit.

INTRODUCTION

As stated in the preceding lesson, a capacitor cannot charge or discharge instantaneously. Mathematically, the process of integration is the direct opposite of differentiation; this is shown by comparing the output waveforms of a differentiating circuit with those of an integrating circuit. In integration, the output is taken from across the capacitor.

SUBJECT MATERIAL

1. Review the charge and discharge action of an R-C circuit.

a. The voltage drop across R is maximum at the instant a voltage is applied.

b. The current in the circuit is maximum at the instant the voltage is applied.

c. Both the current through, and the voltage drop across, R decrease exponentially with time after the initial application of the voltage.

2. Draw the circuit for, and describe the action of, an R-C integrator circuit.

a. Apply a d-c voltage to the circuit; show that, at the first instant, $E_c = 0$, I is maximum, E_r is maximum.

b. Show that the capacitor charges at an exponential rate determined by the RC time constant of the circuit. Draw the waveform of the voltage across the capacitor.

3. Discuss the effects of various integrator RC time constants on an applied voltage.

a. Show that, regardless of the combination of R and C, if the combination produces the same time duration, the circuit operation will not change.

b. Show the effects of a long time constant on an applied voltage.

c. Show the effects of a medium time constant on an applied voltage.

d. Show the effects of a short time constant on an applied voltage.

4. Set up the R-C Time Constant Demonstration Unit, and apply a d-c input from the Power Supply Demonstration Unit.

a. Using the 16-μf. capacitor and a 1.2-megohm resistor, place the vacuum-tube voltmeter across the capacitor, and demonstrate to the class the fact that the capacitor charges at a rate determined by R and C.

b. Take readings at spaced intervals and develop a charging curve for the capacitor.

c. Show on the curve the RC and 2.3 RC time points.

5. Discuss briefly the formula $e = E\epsilon^{-\frac{t}{RC}}$.

6. Discuss the effects of an R-C integrator circuit on various shaped waveforms.

a. Show the effect of a long, medium, and short RC time constant on a square wave.

b. Show the effect of a long time constant on a spiked waveform.

7. Set up the plate-coupled multivibrator unit, and demonstrate to the class the effect of integration, by means of long, medium, and short RC time constants, on a square-wave input.

8. Discuss briefly the applications of the R-C integrator circuit in filter networks, and as a charging device for a saw-tooth generator.

9. Set up the thyratron saw-tooth generator, and demonstrate the output saw-tooth waveform. Do not fully discuss the theory of operation of the saw-tooth generator, since it will be covered in the lesson on sweep generators.

CONCLUSIONS

R-C integrator circuits find wide application in radar and radio circuits. Probably the most important application in radar is in saw-tooth generator circuits. These will be covered more completely later in the course.

ORAL QUIZ

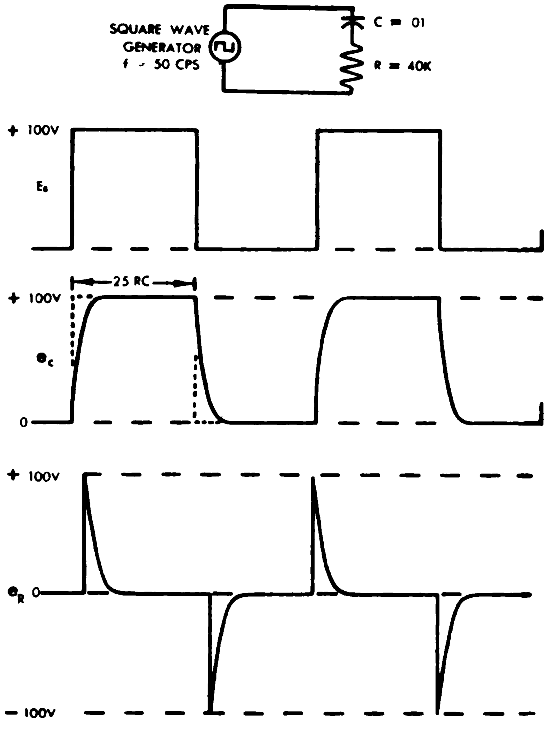
1. What factors control the charging rate of a capacitor?

2. What type of waveform is produced by a medium time constant R-C integrator circuit when a square wave is applied as an input?

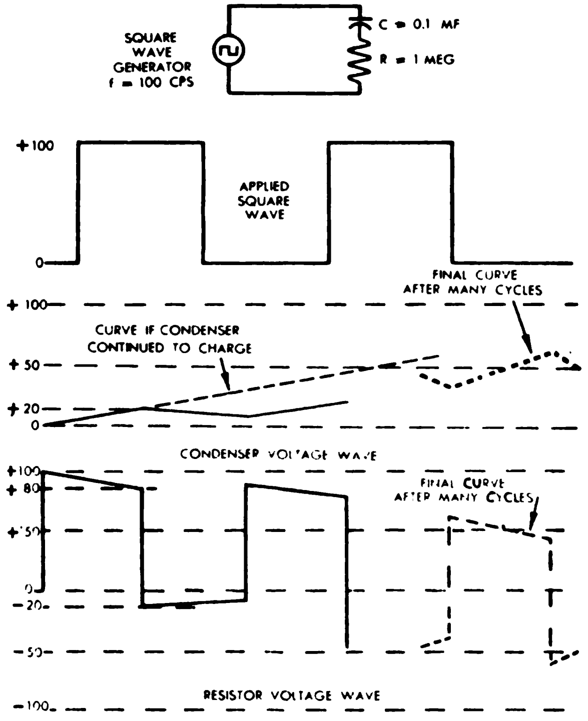
3. What percentage of full charge will have been accumulated on a capacitor after 2.3 RC time?

4. What is the principal application of R-C integrator circuits?

5. In practice, will a capacitor ever fully charge to the applied voltage? Why?



Waveshapes for Short Time Constant RC Circuit



Waveshapes for Long Time Constant RC Circuit

LESSON PLAN No. 8

SUBJECT

LR time constants (differentiation and integration).

OBJECTIVE

To acquaint the student with the theory and applications of LR time constant circuits.

INTRODUCTION

Although the LR time constant is not used nearly so widely in radar as the RC time constant, there are applications in which resistance and inductance are involved. It is important to understand why it takes time for a voltage or current to decay in an L-R circuit.

SUBJECT MATERIAL

1. Review the properties of inductance.

a. Discuss the fact that an inductance also contains a resistive component, the wire with which it is wound.

b. Explain that a practical inductor has distributed capacitance. Show that this capacitance exists between windings. Explain further that this could cause the coil to oscillate at some frequency. Explain these points only briefly; they will be covered more fully later in the lesson.

2. Draw and explain the charge and discharge of an L-R circuit.

a. Discuss the formula $t = L/R$.

b. Explain, with waveforms, L-R charging, showing $e_l = E_{app.}$, I is minimum, and e_r is minimum at initial instant. Show that e_l will decay, while I and e_r will increase at an exponential rate determined by the values of L and R.

c. Explain, with waveforms, L-R discharging.

d. Explain the application of the universal time curve L-R circuits.

3. Discuss briefly the formula $i = \frac{E}{R}\left(1 - \epsilon^{\frac{Rt}{L}}\right)$

4. Discuss the effect of applying a voltage with steep leading and trailing edges to an inductance.

a. A coil has distributed capacitance which causes it to appear as a parallel-resonant tank circuit.

b. Theoretically, an L-R circuit should perform as indicated in paragraph 2 of this LESSON PLAN, but because of the distributed capacitance an applied voltage with a steep leading edge can shock the coil into oscillation. If the coil is sufficiently damped by resistance, the circuit will operate in the manner described in paragraph 2.

CONCLUSIONS

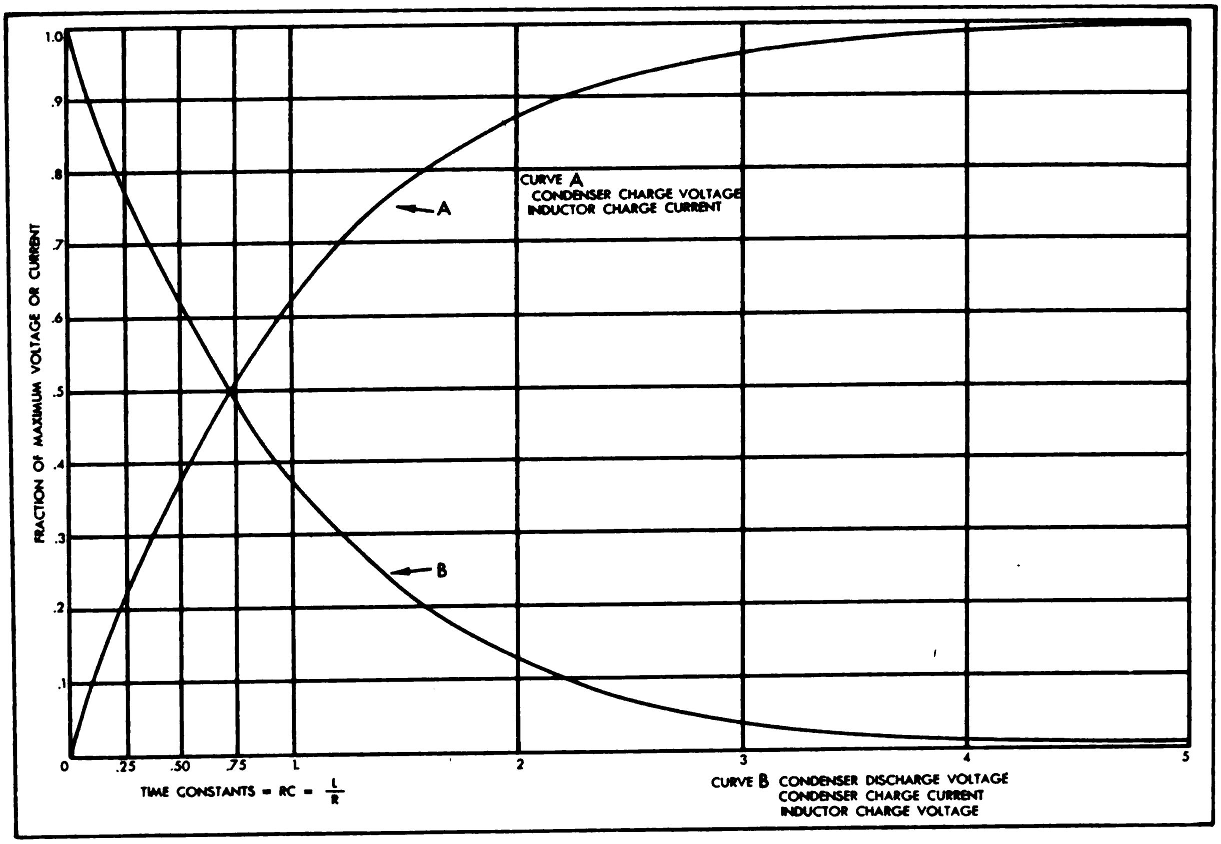
The action of L-R circuits is apparent in filter networks and in shock-excited oscillators. Where the rise and decay of voltages and currents are not at a sinusoidal rate, it is evident that the exponential rate is involved. This peculiar action will be demonstrated more forcefully in the waveforms of the single-swing blocking oscillator and the shock-excited oscillators which will be studied later in this course.

ORAL QUIZ

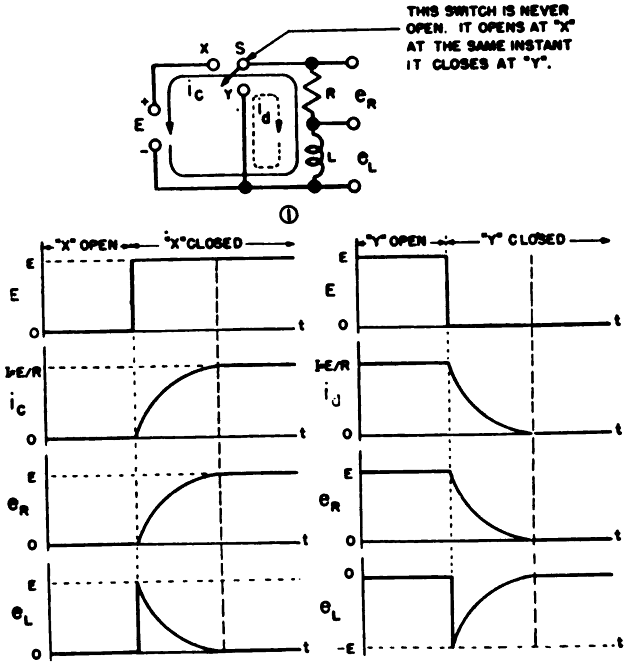
1. At the instant a voltage is applied to an L-R circuit, what is the relationship between e_l, e_r, and E_{app}?

2. What factors determine the rate of decay of e_l?

3. What is the formula for determining the time constant of an L-R circuit?



Universal Time Constant Chart



Charge and Discharge of R-L Circuit

EXAMINATION No. 2

1. c . If a sine wave is applied to a short time constant R-C circuit, the signal across the resistor will be in the form of:

   a. A square wave.
   b. A peaked wave.
   c. A phase-shifted sine wave.
   d. A sine wave in phase with the applied voltage.

2. a . If a saw-tooth wave is applied to an R-C circuit having a short time constant:

   a. The voltage across the capacitor will be very nearly equal to the input voltage.
   b. The voltage across the resistor will be zero.
   c. The voltage across the capacitor will be zero.
   d. None of the above is correct.

3. a . If a square wave is applied to an R-C network that has a very short time constant, the output across the capacitor will be in the form of:

   a. A square wave.
   b. A peaked wave.
   c. A saw-tooth wave.
   d. None of the above is correct.

4. c . If a saw-tooth wave having a rise time of .0001 sec. and a peak voltage of 100v is applied to an R-C network with a time constant of .005 sec., the voltage across the resistor at the end of .00005 sec. will be:

   a. 63 volts.
   b. 31.5 volts.
   c. 50 volts.
   d. None of the above is correct.

5. Referring to figure 1, how long will it take the capacitor to charge to 126 volts?

470 microseconds.

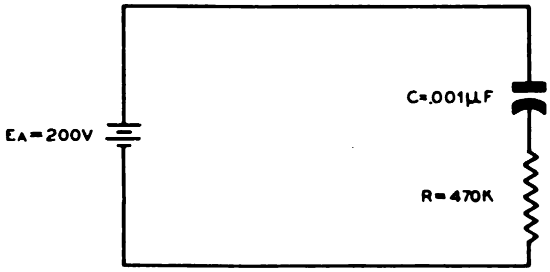


Figure 1

6. Referring to figure 2, draw the waveforms that will appear across the resistor and capacitor when C = .25 μf. and R = 100 k.

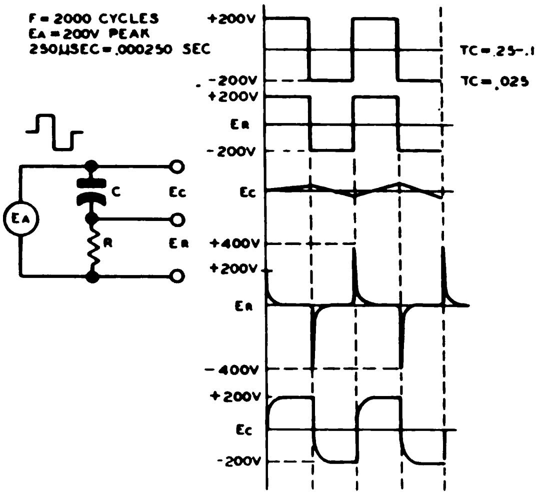
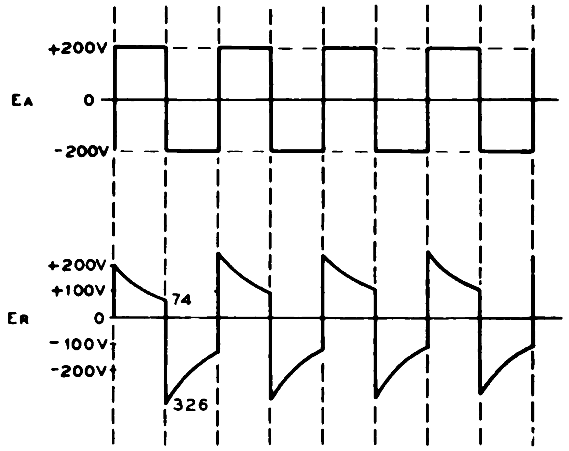


Figure 2

7. Referring to figure 2, draw the waveforms that will appear across the resistor and capacitor when C = .001 μf. and R = 10k.



Suggested Drawing for Question 9

8. What will be the peak value of E_R in problem No. 7?

400 volts.

9. Referring to figure 2, if R = 25k and C = .01 μf., plot the waveform with values across R for a time duration of 1000 μsec.

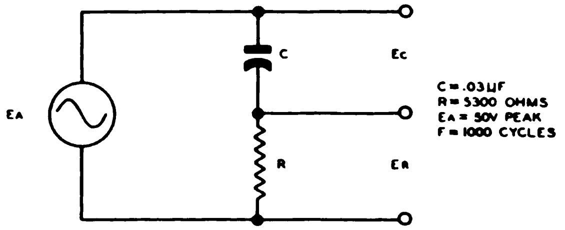
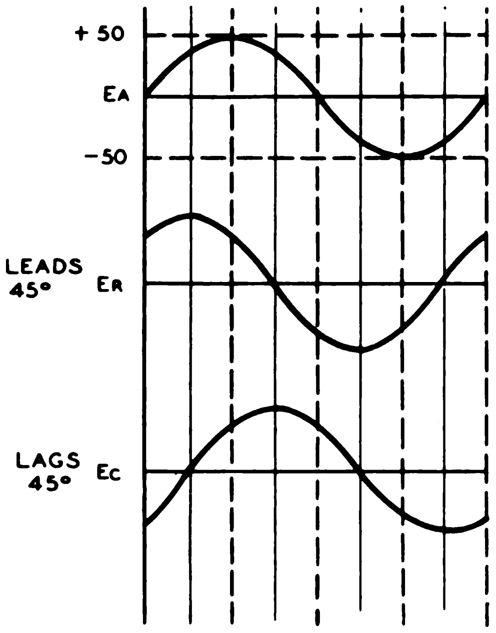


Figure 3

10. Referring to figure 3, draw, in the space provided, the waveforms that would appear across the resistor and capacitor, showing time relationship.



Suggested Drawing for Question 10

11. Referring to figure 3, calculate the peak voltage across the resistor.

35.3 volts.

12. c. An R-C phase-shift oscillator gives a very nearly sinusoidal output if:

a. Grid-leak bias is used.

b. Reduced plate voltage is used.

c. The bias is so adjusted that oscillations barely take place.

d. The phase shift of each R-C network is the same.

13. c. Referring to figure 4, if R2 were increased, the:

a. Output would be nonsinusoidal.

b. Output frequency would increase.

c. Output frequency would decrease.

d. Oscillator would not operate, because the feedback would not be exactly 180°.

14. b. Referring to figure 4, if R3 were to open:

a. The frequency of oscillations would change.

b. There would be no output, since oscillations would cease.

c. The output would be distorted.

d. The output would decrease in amplitude.

15. c. Oscillations will take place in a Wein-bridge oscillator when the:

a. Degenerative feedback is 180° out of phase with the plate.

b. Regenerative feedback is 180° out of phase with the degenerative feedback.

c. Regenerative feedback is equal to or greater than the degenerative feedback.

d. Regenerative feedback is less than the degenerative feedback.

16. c. The output of a Wein-bridge oscillator is very constant, because, as the amplitude tends to rise, the:

a. Regeneration is decreased.

b. Phase of the degeneration is changed.

c. Degeneration is increased.
d. Plate voltage is decreased.

17. Why is it necessary to use a high-gain tube in an R-C phase-shift oscillator?

Because of high attenuation in the phase-shift network.

18. List three advantages of a Wein-bridge oscillator.

Excellent sine-wave output.
Uniform amplitude over a wide frequency range.
Excellent frequency stability.

19. An inductance of 120 millihenries and a resistor of 150 ohms are connected in series, with a 5-volt battery connected across the terminals. Using formulas for L/R = time, compute:

a. The voltage across the resistor at the end of 1840 microseconds.

4.5 volts.

b. The voltage across the inductance at the end of 800 microseconds.

1.85 volts (based on 37%).

20. In the above problem, what is the current at the end of 1840 microseconds?

30 ma.

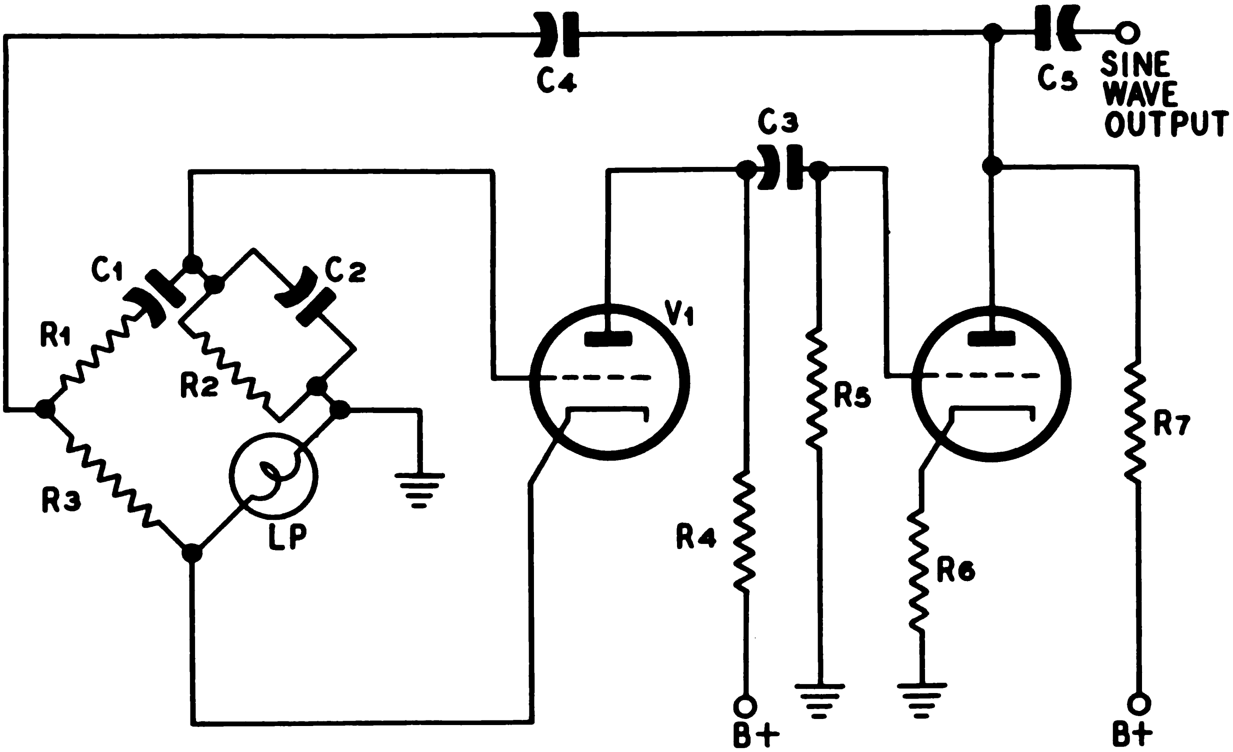


Figure 4

LESSON PLAN No. 9

SUBJECT

Series and parallel diode limiters.

OBJECTIVE

To explain the theory and applications of series and parallel diode limiters.

MATERIAL REQUIRED

1. Series Diode Limiter Demonstration Unit.
2. Parallel Diode Limiter Demonstration Unit.
3. Audio-signal generator.
4. Five-inch cathode-ray oscilloscope.
5. Vacuum-tube voltmeter.
6. Bias Supply Laboratory Chassis.

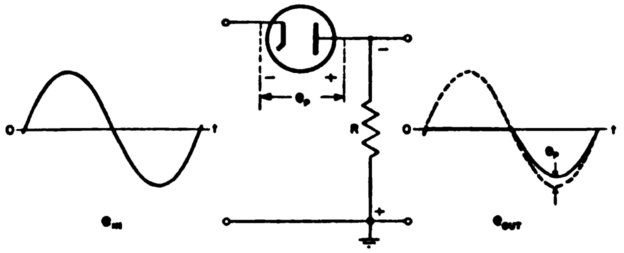


Figure 1

INTRODUCTION

The term "limiting" refers to the removal, by electronic means, of one extremity or the other of an input wave. Circuits which perform this function are called "limiters" or "clippers."

SUBJECT MATERIAL

1. Review the operation of diodes, emphasizing the following points:

a. A diode will conduct only when its plate is more positive than its cathode.

b. When the plate of a diode is made more positive, more current will flow through the tube. Similarly, when the plate is made less positive, less current will flow through the tube.

c. When a diode is not conducting, it appears theoretically, as an infinite impedance, or open circuit. Unfortunately, this is not so in a practical diode, because of the interlectrode capacitance between plate and cathode.

d. When a diode is conducting, the impedance between the plate and cathode falls to a value of approximately 550 ohms.

2. Draw a circuit for, and describe the operation of, a series diode limiter, Figure 1.

a. Discuss the operation of the series diode circuit used to limit positive signals.

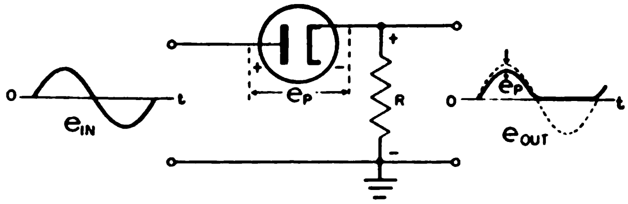


Figure 2

b. After analyzing the circuit, insert a positive voltage source, and then a negative voltage source, in series with R, and describe its effect on circuit operation with an input sine wave applied. Show the waveform of the output voltage.

c. Explain the operation of the series diode circuit used to limit negative signals, Figure 2.

d. After analyzing the circuit, insert a positive voltage source, and then a negative voltage source, in series with R, and show its effect on circuit operation with an input sine wave applied. Show the waveform of the output voltage.

3. Illustrate and explain the operation of parallel diode limiters.

a. Draw and analyze, with waveforms, the positive limiter circuit, Figure 3.

b. Show, with waveforms, the operation of the negative limiter circuit, Figure 4.

c. Discuss the operation of, and illustrate the output obtainable from, the positive limiter circuit employing a parallel diode, limiting above ground, Figure 5.

d. Show, with waveforms, the operation of the negative limiter circuit of a parallel diode, limiting below ground, Figure 6.

e. Demonstrate, with waveforms, a parallel diode limiter circuit capable of removing all but the negative peaks of an input signal voltage, Figure 7.

f. Explain and illustrate, with waveforms, the positive peak retainer circuit of the parallel diode limiters which pass peaks only, Figure 8.

g. Draw and explain the double-diode limiter circuit, employing waveforms, Figure 9.

4. Set up the Series and the Parallel Diode Limiter Demonstration Unit, and illustrate the operation of the circuits discussed in paragraphs 2 and 3 of this LESSON PLAN.

CONCLUSIONS

Limiters are useful in wave-shaping circuits when it is desirable to square off the amplitude extremities of the applied signals. They are frequently used to eliminate unwanted noise voltages.

ORAL QUIZ

1. Under what conditions will a diode conduct?

2. When a series diode limiter is clipping, is the diode conducting or not?

3. When a parallel diode limiter is clipping, is the diode conducting or not?

4. What is the major advantage of a double-diode limiter circuit?

5. Give two uses of limiter circuits.

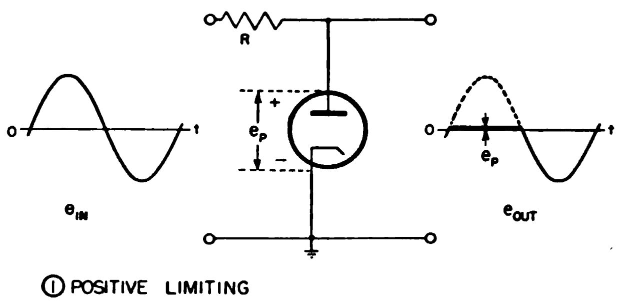


Figure 3

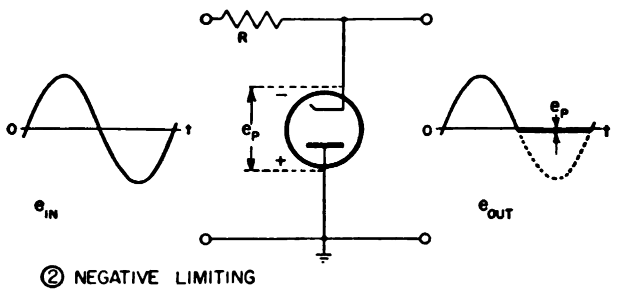


Figure 4

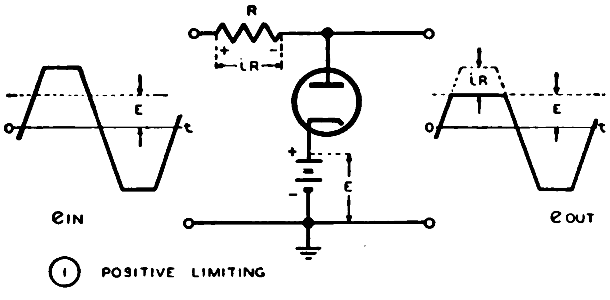


Figure 5

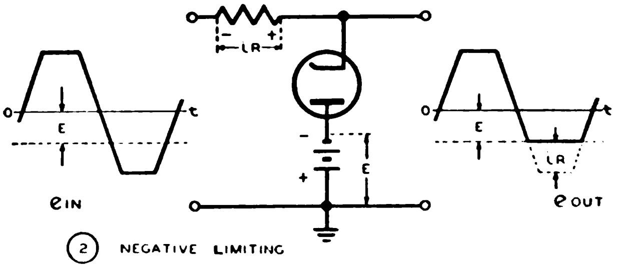


Figure 6

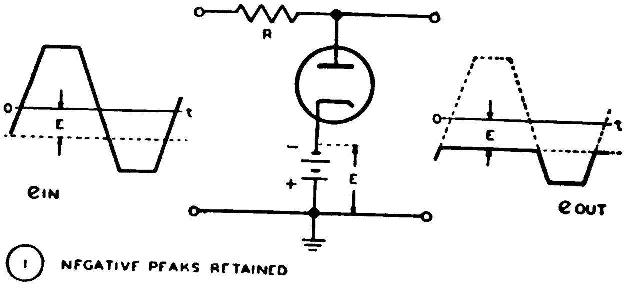


Figure 7

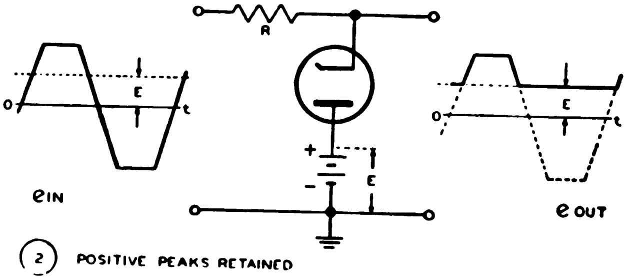


Figure 8

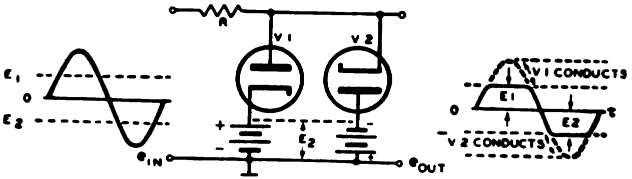


Figure 9

LESSON PLAN No. 10

SUBJECT

Triode and pentode limiters.

OBJECTIVE

To familiarize the students with the theory and applications of triode and pentode limiter circuits.

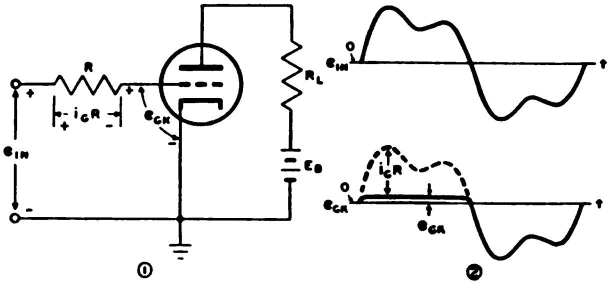


Figure 1

INTRODUCTION

The diode limiters studied to date perform the same function as the triode and pentode limiters. However, diode limiters have one serious disadvantage in that they are not capable of signal amplification, whereas the triode and pentode limiters do provide gain, as well as limiting action.

SUBJECT MATERIAL

1. Review the following points concerning triodes and pentodes:

a. When a triode or pentode draws grid current, its grid-to-cathode impedance falls from a very high value to a very low value (about 1000 ohms).

b. In an amplifier circuit, when the tube is driven to cutoff, the voltage at the plate rises to the value, B+, and remains there as long as the tube is cut off.

c. In an amplifier circuit, when the tube is made to conduct very heavily, the voltage at the plates falls to a very low value, and remains there as long as the tube continues to conduct very heavily.

2. Draw the circuit of, and discuss the operation of, a grid-limiter circuit, Figure 1

a. Explain the operation of the unbiased grid-limiter circuit, showing the input, grid, and plate waveforms. Point out the relationship between the value of the grid-limiting resistor and the grid-to-cathode impedance when the tube draws grid current, and when it does not.

b. Draw and explain the grid-limiter circuit in which the cathode is grounded and the grid is biased by a negative voltage. Also describe the operation of the grid-limiter circuit using automatic cathode bias. Emphasize the fact that the tube will not draw grid current until the input voltage exceeds the negative bias voltage, Figure 2 and Figure 3.

3. Discussion saturation limiting:

a. Draw and explain, using waveforms, the tube characteristic curves showing saturation limiting, Figure 4.

b. Using waveforms, compare grid limiting and saturation limiting.

c. State that the requirements of a saturation limiter are: (1) a high value of plate load resistance; and (2) a low plate-supply voltage.

4. Discuss cut-off limiting:

a. Draw and explain, using waveforms, curves illustrating the squaring of the plate-voltage waveform due to cut-off limiting, Figure 5.

b. Show how changes in bias affect the cutoff point, and therefore, the plate waveform.

c. Draw and explain, using waveforms, the formation of a square wave by both grid limiting and cut-off limiting, Figure 6.

5. Discuss the overdriven amplifier, Figure 7.

a. Using waveforms, explain the formation of a square wave by saturation and cut-off limiting.

b. Make sure that the class understands which flat portion of the plate waveform is caused through cutoff and which is caused by saturation.

6. Briefly discuss the fact that pentodes may be substituted for triodes in these circuits, because of the higher gain of the pentodes.

7. Give some specific examples of the use of diode and triode limiter circuits.

CONCLUSIONS

Generally, triode and pentode limiters find a wider application in radar systems than do other types of limiters, because of their ability to amplify the signal as well as clip it. The square waves produced in this manner have a variety of applications, notable among which is a gate pulse for activating other circuits.

ORAL QUIZ

1. Under what conditions does a triode or pentode draw grid current?
2. When a tube is cut off, does its plate voltage go to a minimum or maximum? Explain.
3. When a tube is driven to saturation, what does its plate waveform look like?
4. What is an overdriven amplifier?
5. How is grid limiting accomplished?

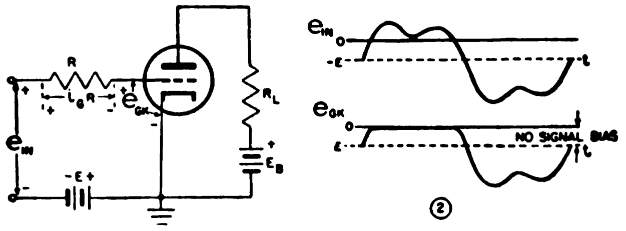


Figure 2

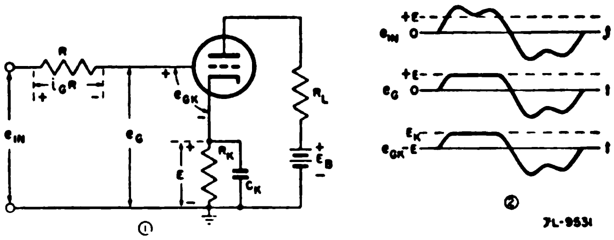


Figure 3

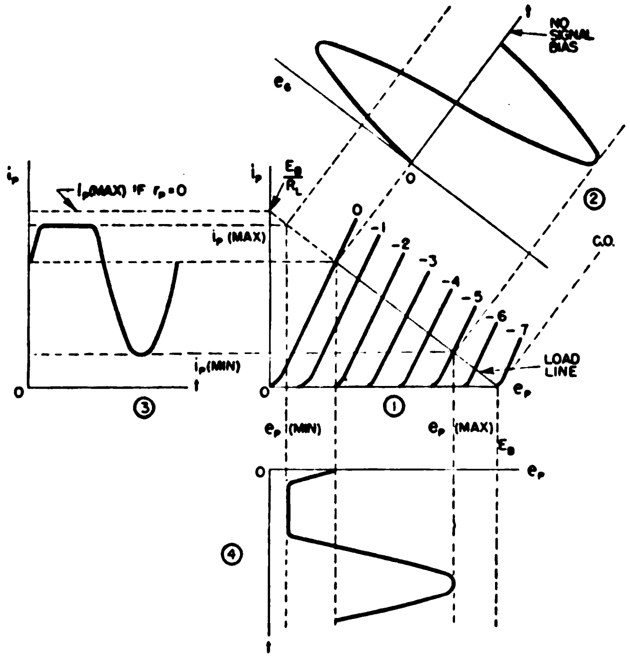


Figure 4

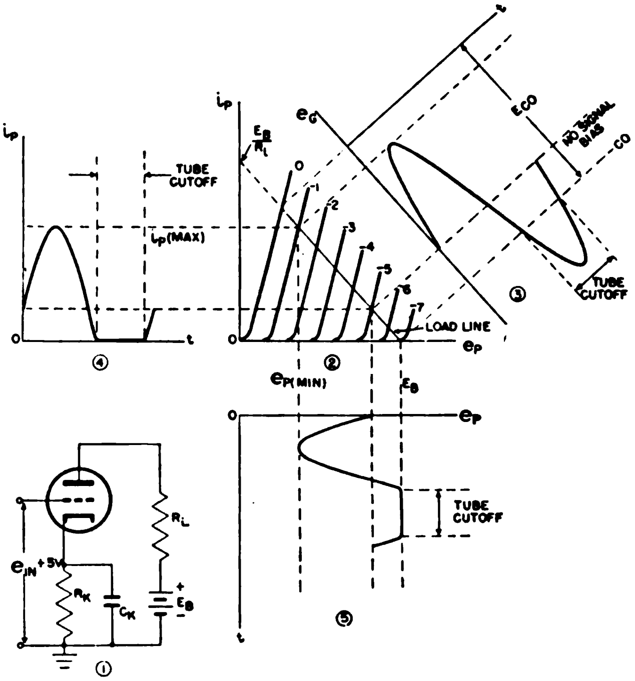


Figure 5

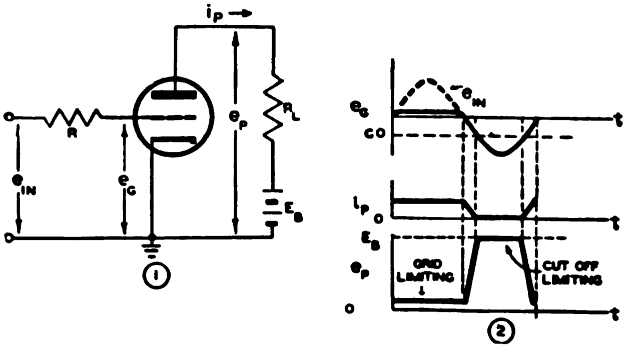


Figure 6

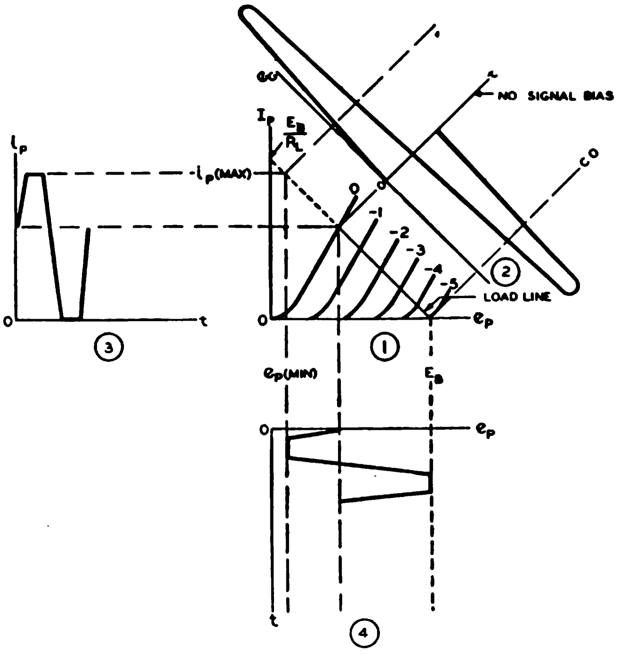


Figure 7

LESSON PLAN No. 11

SUBJECT

Peaking circuits.

OBJECTIVE

To explain the theory of operation of peaking circuits, and to show applications of these circuits.

MATERIAL REQUIRED

1. Peaking Circuit Demonstration Unit.
2. Power Supply Demonstration Unit.
3. Five-inch cathode-ray oscilloscope.
4. Power cord to apply 60-cycle line voltage to the input of the peaking circuit.

INTRODUCTION

The generation of spike-type waveforms is essential in a radar system. Generally, a spike waveform is the end product of modification of a sine wave. In some cases, it is necessary to square and differentiate the sine wave, while in other cases, spikes may be formed directly from the sine wave without requiring a maze of circuits to perform this function.

SUBJECT MATERIAL

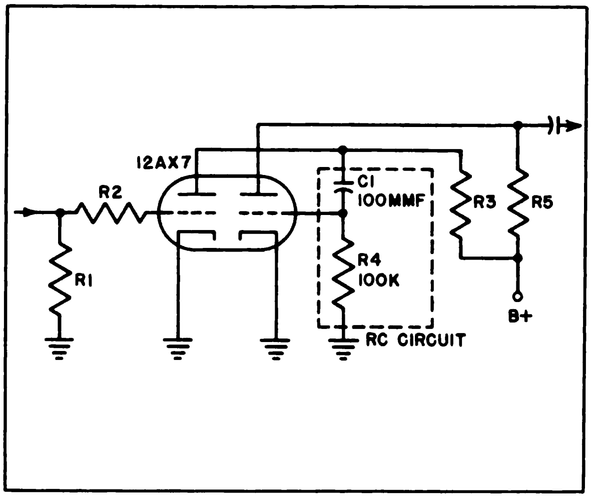
1. Review, briefly, the action of a short R-C time constant differentiator circuit to which is applied a square-wave voltage.
2. Draw and explain the schematic diagram of a typical R-C differentiator amplifier circuit, used as a peaker.
    a. Apply a typical waveform to the grid of the grid limiter.
    b. Decouple the differentiator from the amplifier, and show that a square wave is produced at the plate of the limiter.
    c. Give an explanation of the peaking action obtained when the differentiator is connected to the plate circuit of the limiter.
    d. Explain the action of the following amplifier circuit on the peaked wave appearing at its grid.
3. Set up the Peaking Circuit Demonstration Unit, and apply the 110-volt 60-cycle line voltage as the signal input to the peaker.

Observe the waveforms at the various test points, and discuss their formation.

4. Review the characteristics and properties of inductance.
5. Describe a "saturable inductor," and explain its operation, using graphs and waveforms.
6. Draw, on the blackboard, saturable inductor peaking circuit, and explain its operation in a step-by-step analysis.
    a. Use vectors to develop the presentation.
    b. Use waveforms to aid the circuit analysis.
7. Give specific examples of applications of peaking circuits.

CONCLUSIONS

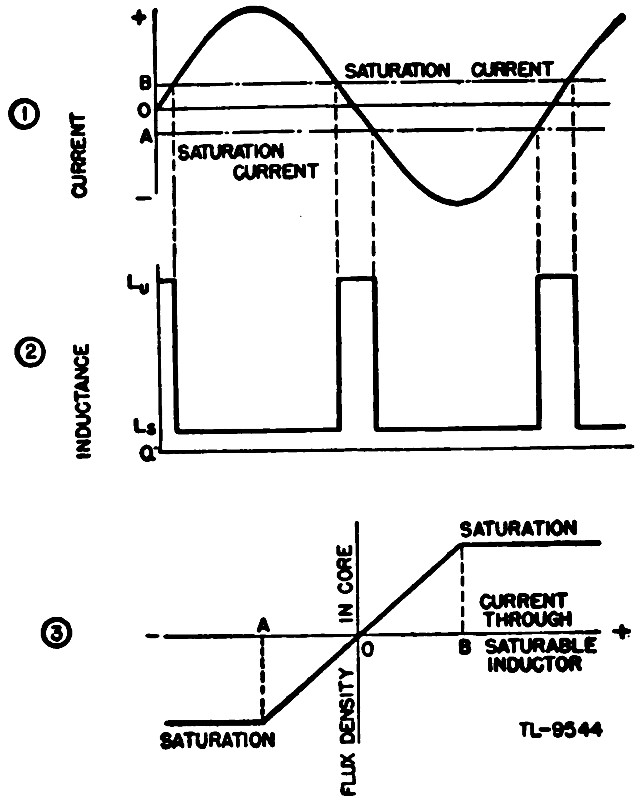
In the development of trigger pulses for use in controlling the operation of various circuits, "peakers" are often employed. In order to produce peaked pulses, it is necessary to use a circuit capable of distorting an input signal in such a way as to produce an output waveform whose time duration is shortened and whose leading edge is as nearly vertical as possible. This is accomplished through the use of the peaking circuits herein described.



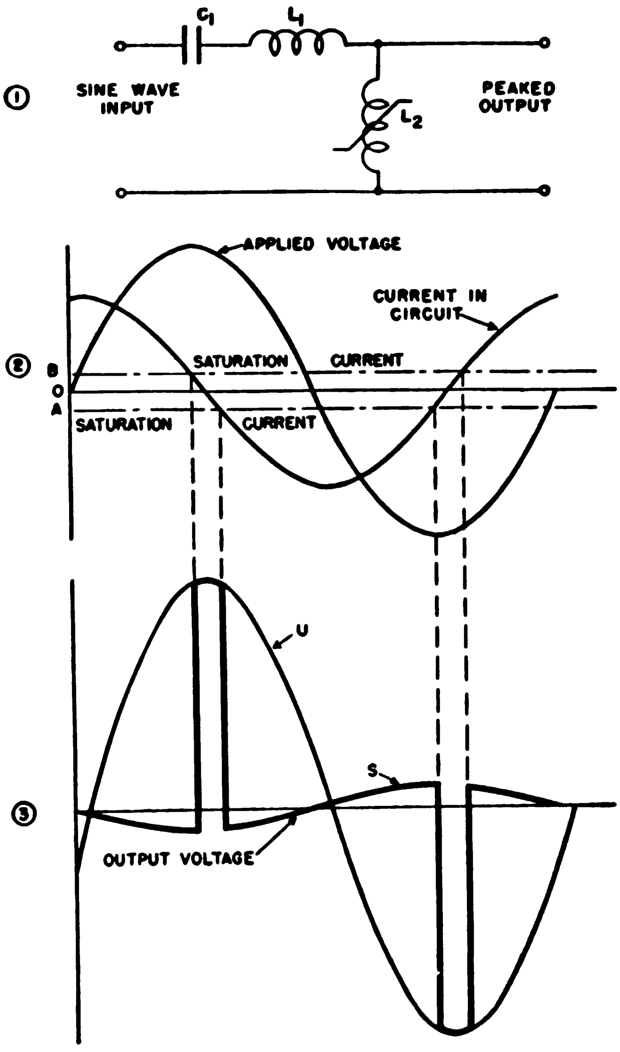
R-C Differentiator Circuit Application

ORAL QUIZ

1. In an R-C peaking circuit, why is the positive spike smaller than the negative spike, in the waveform observed at the grid of the amplifier?
2. What causes the value of inductance of a saturable inductor to fall to a very low value?
3. In the saturable-inductor circuit, before the inductor is driven to saturation, does the circuit appear inductive, capacitive, or resistive? Why?



Relationship between Current and Inductance in Saturable Inductor



Peaking by means of Saturable Inductor

LESSON PLAN No. 12

SUBJECT

Wave-shaping circuits.

OBJECTIVE

To explain the operational theory and to describe some applications of wave-shaping circuits.

INTRODUCTION

A wave-shaping circuit is essentially one which is designed to produce, at its output, a sharp-spike waveform by distorting the original input waveform. This type of circuit finds its widest application in the production of trigger pulses for radar systems.

SUBJECT MATERIAL

1. Draw the circuit shown in Fig 1 and give a step-by-step explanation of the circuit operation.

a. Select an input sine wave signal of definite amplitude, e.g., 50v peak-to-peak.

b. Establish the cutoff and saturation points for V1 and V2.

c. Select a definite frequency of input voltages, e.g., 1000 cycles, so that the values for the differentiating circuit C1 and R may be calculated to produce a short time constant.

d. Using waveforms explain the circuit operation, showing the formation of these waveforms.

e. Set up theoretical troubles in the circuit, and show what effect they would have on the operation of the circuit.

2. Draw the circuit shown in Fig 2 and give a step-by-step analysis of circuit operation.

a. Show the step-up action of the transformer.

b. Explain how the potentiometer is used to select a portion of the input voltage.

c. Show the action of the grid limiting and cutoff limiting in tube V1.

d. Show the action of the circuit of V2.

e. Emphasis should be placed on the effects produced by changes in the bias of tube V2, which show up in the waveforms designated as E and F.

f. Set up theoretical troubles in the circuit, and show what effect they would have on the operation of the circuit.

3. Set up the following demonstration units. Explain the operation of the circuits of the demonstration units.

a. Set up the parallel dual diode limiter circuit, with bias supply in the cathode and plate circuits, so that, with a sine-wave input, a square-wave output may be obtained.

b. Select values for C1 of the parallel limiter and R1 of the series limiter demonstration units so that this coupling combination has a short RC time constant, to produce differentiation of the square wave produced in the parallel diode limiter.

c. In the Series Diode Limiter Demonstration Unit, first connect V1A in the circuit to show that the positive pip will be developed as an output by this wave-shaping circuit. Next, connect V1B in the circuit to show that the negative pip will be developed as an output by this wave-shaping circuit.

d. Apply a sine-wave input from the audio generator to the parallel diode limiters. Using the scope, show the class the waveforms at important points in the circuit.

e. Demonstrate the effects of open resistors, faulty capacitors, and faulty tubes. Also, show the effect of bias variations on the parallel limiters.

4. Give some specific examples of the use of the wave-shaping circuits discussed in this lesson.

CONCLUSIONS

Generally, wave-shaping circuits are nothing more than interconnected limiting circuits and differentiating networks. These are widely used in the production of sharp, short-duration trigger pulses.

ORAL QUIZ

1. For what purpose are wave-shaping circuits generally used?

2. Draw and explain the action of a wave-shaping circuit.

3. Set up the demonstration units in this lesson, and explain the operation of the circuits demonstrated to the class.

4. Set up the demonstration units used in this lesson, and describe a method of trouble-shooting these circuits.

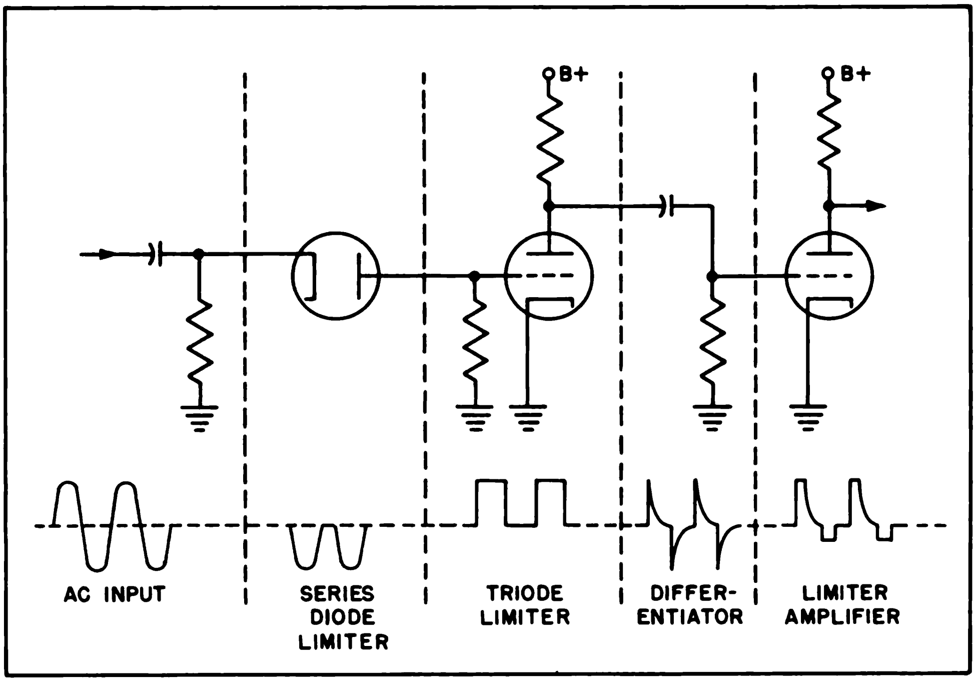


Figure 1

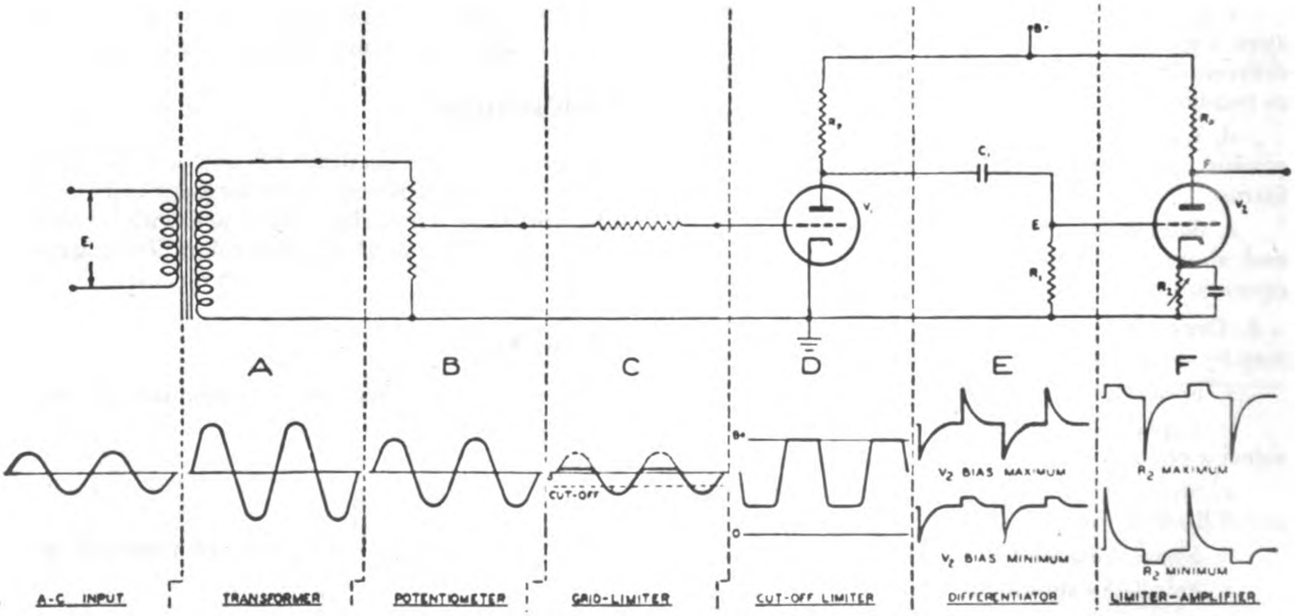


Figure 2

EXAMINATION No. 3

NOTE: A cover page, similar to the one shown on page 8, should be reproduced with this examination for student use.

1. a . If saturation limiting with a low-amplitude input signal is desired, it can be had by using a:
   a. Large plate load resistance and a low plate-voltage supply.
   b. Low plate voltage and high screen voltage.
   c. Large value of resistance in series with the grid.
   d. Low value of grid-leak resistance.

2. b . The inductance in a saturable coil is maximum when:
   a. The current through the coil passes through its maximum value.
   b. The current passes through its zero point.
   c. The current passes through its maximum value in the reverse direction.
   d. The voltage across the coil is minimum.

3. d . The main characteristic of a peaker circuit is its ability to produce a waveform that has a:
   a. Sharp trailing edge, and short duration.
   b. Sloping leading edge, and flat top.
   c. Sloping leading edge, and short duration.
   d. Sharp leading edge, and short duration.

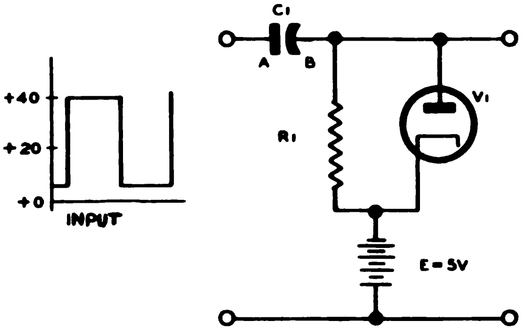


Figure 1

4. c . The circuit in figure 1 will clamp a wave:
   a. Positive to a negative 5v.
   b. Positive to a positive 5v.
   c. Negative to a negative 5v.
   d. Negative to a positive 5v.

5. b . The capacitor in figure 1 will maintain a charge of about:
   a. 35v, A positive and B negative.
   b. 45v, A positive and B negative.
   c. 15v, A positive and B negative.
   d. 35v, A negative and B positive.

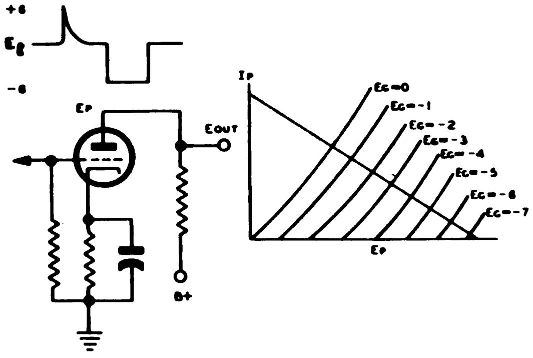
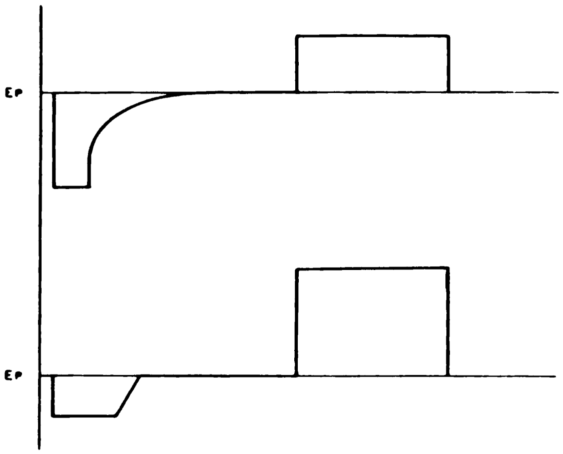


Figure 2

6. Referring to figure 2, draw the waveform at the plate, assuming that the bias on the tube is −5 volts.

7. Referring to figure 2, draw the waveform at the plate, assuming that the bias on the tube is −1 volt.



Suggested Drawing (Questions 6 and 7)

8. d. In figure 3, the circuit of V1 is a:
   a. Positive diode clamper.
   b. Phase-shift oscillator.
   c. Square-wave generator (multivibrator).
   d. Wein-bridge oscillator.

9. c. In figure 3, the circuit of V4 is a:
   a. Positive diode clamper.
   b. Negative diode clamper.
   c. Positive parallel limiter.
   d. Negative parallel limiter.

10. Referring to figure 3, draw the waveform that will appear at the grid of V3.

11. Referring to figure 3, draw the waveform that will appear at the plate of V3.

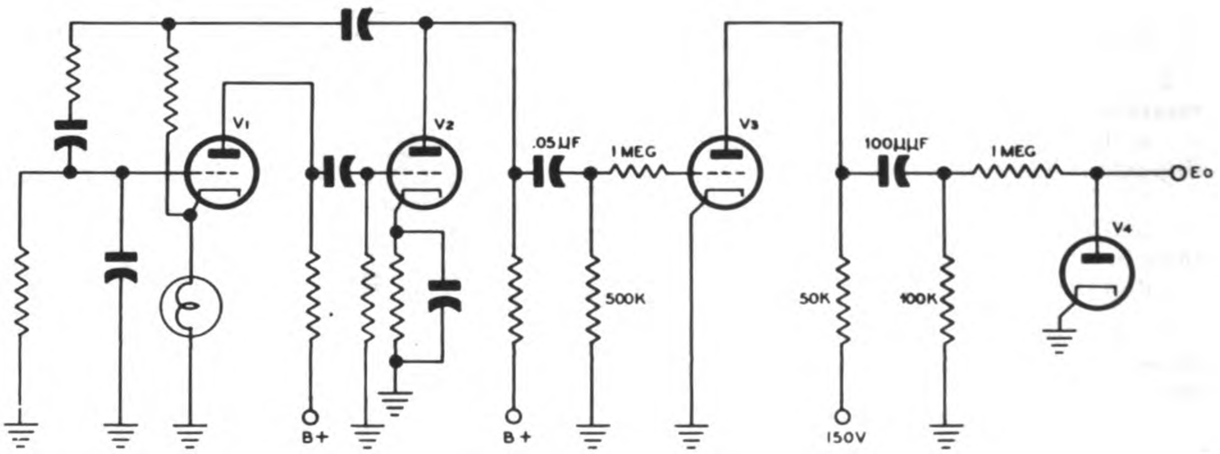
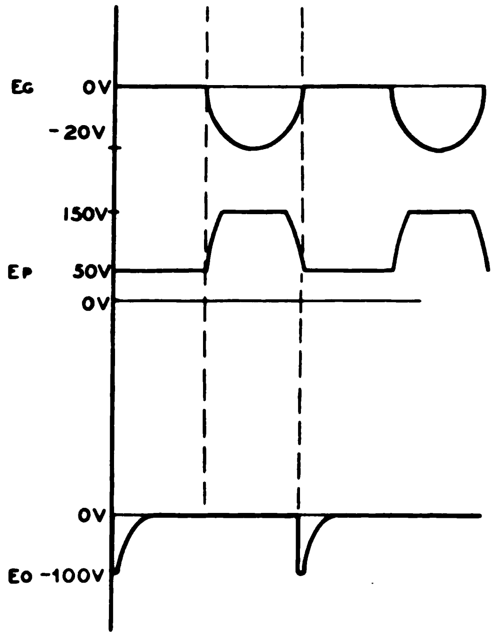


Figure 3



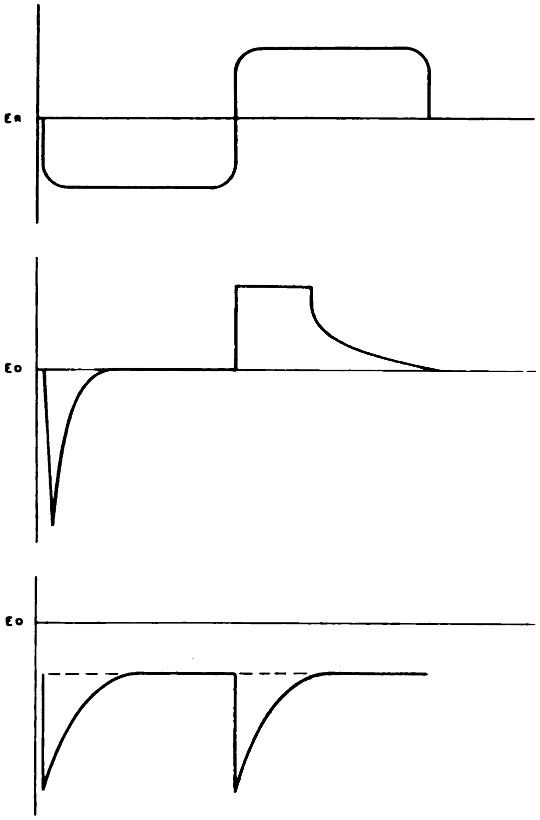
Suggested Drawings
For Questions 10, 11, and 12

12. Referring to figure 3, draw the output (E_o) waveform, across V4.

13. Referring to figure 3, calculate the peak amplitude of the output (E_o) wave.

14. Referring to figure 4, draw the waveform that will appear at the plate of V1.

15. Referring to figure 4, draw the waveform that will appear at the output.



Suggested Drawing
For Questions 14, 15, and 16

16. Referring to figure 4, draw the waveform that would appear at the output if the battery E_G were reversed.

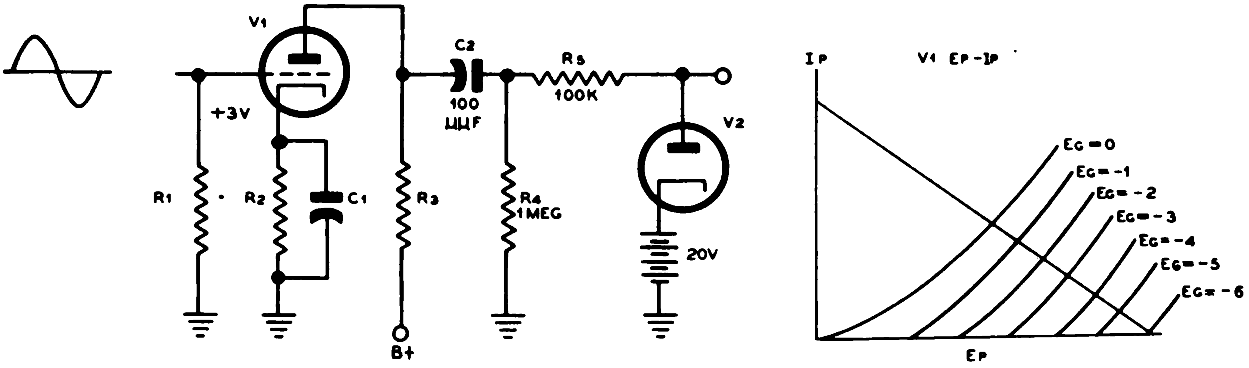


Figure 4

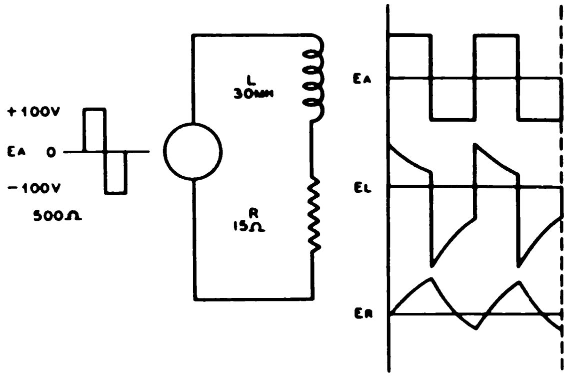


Figure 5

17. Referring to figure 5, draw the waveforms that will appear across R and L.

18. a. A parallel diode limiter:

a. Conducts when limiting.

b. Does not conduct when limiting.

c. Is in series with the limited signal.

d. Represents a resistance of about 5000 ohms when conducting.

19. c. Which of the following statements does *not* describe the action of a limiter?

a. It can be used to clip off the top of a waveform.

b. It can be used to pass a signal of only one polarity, and exclude others.

c. It can be used to determine, and hold, a reference-voltage level.

d. It can be used to produce square waves from sine waves.

20. When a series diode limiter is producing the clipping action is the diode in a conducting or non-conducting state?

Non-conducting.

LESSON PLAN No. 13

SUBJECT

Clamping circuits.

OBJECTIVE

To teach the operating theory and to give applications of diode, triode, and synchronized clamping circuits.

MATERIAL REQUIRED

1. Diode Clamper Demonstration Unit.
2. Bias Supply Laboratory Chassis.
3. Thyratron Saw-tooth Generator Demonstration Unit.
4. Plate-Coupled Multivibrator Demonstration Unit.
5. Five-inch cathode-ray oscilloscope.
6. Power Supply Demonstration Unit.

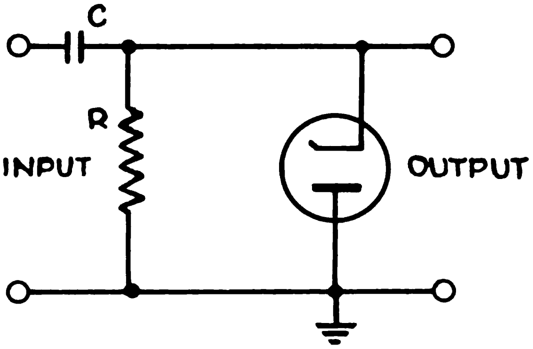


Figure 1

INTRODUCTION

A circuit which functions to hold either amplitude extreme of a waveform to a given reference level of potential is called a clamping circuit; the terms "d-c restorer" and "base-line stabilizer" are also commonly used.

SUBJECT MATERIAL

1. Review the action of R-C coupling networks.

a. Explain that the waveform at the plate of the tube is a voltage varying about a positive d-c potential, but after passing through the R-C coupling network, it becomes a voltage varying about a new reference level usually zero, i.e., ground potential.

b. Using the waveforms showing grid-voltage variation with respect to definite reference potential, explain the difference between clamped and unclamped waveforms.

2. Present the explanation of the positive clamper circuit; apply a square-wave voltage to the input, and give the class a detailed explanation of circuit operation, Figure 1.

Show that the R-C combination at the clamper input is a long time constant when the diode is not conducting, but that a very short time constant circuit exists when the tube is conducting, because of the low impedance of the tube when current flows, Figure 2.

3. Using a negative clamper circuit, apply a square-wave input, and give the class a detailed explanation of circuit operation. Draw the waveforms present in the circuit, to facilitate the discussion, Figure 3, Figure 4.

4. Explain the operation of a typical grid-clamper circuit, Figure 5.

Show that the R-C combination at the clamper input diode when the tube draws grid current; this causes the input circuit of a triode clamper to acts as a negative clamper.

5. Using a clamping circuit which establishes a reference potential of −10 volts, present to the class a detailed explanation of circuit operation; draw waveforms as you proceed, to facilitate the discussion, Figure 6.

6. Set up the Diode Clamper Demonstration Unit.

a. Connect the output of the Plate-Coupled Multivibrator Demonstration Unit as an input to the clamper, and feed the output of the clamper directly to the vertical-deflection-plate terminals at the rear of the oscilloscope.

b. First, feed the output of the clamper through a capacitor, and show the class that the waveform varies about the center line of the scope face; then show the effects of both positive and negative clamping of the square wave.

c. Insert a bias voltage in series with the clamper circuit, and show the class its effect in clamping the position of the waveform, as explained in paragraph 5.

d. Apply the output of the Thyratron Saw-tooth Generator Demonstration Unit as an input

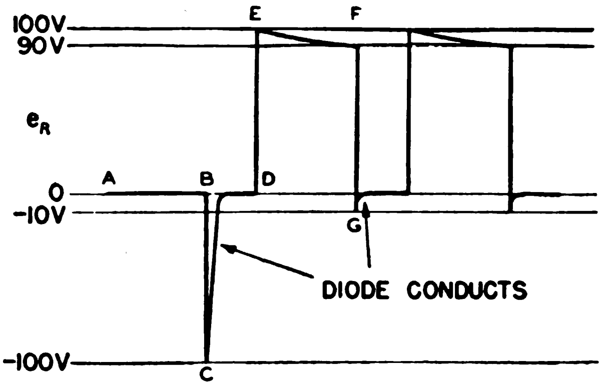


Figure 2

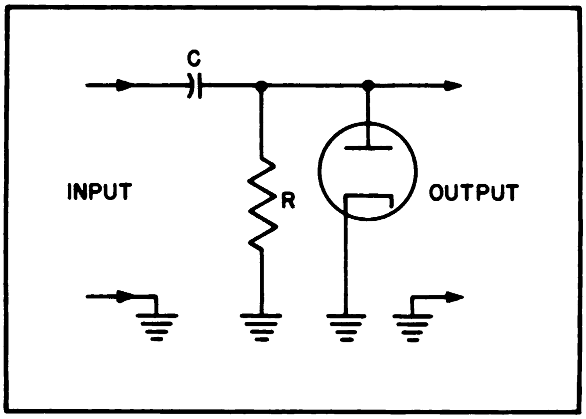


Figure 3

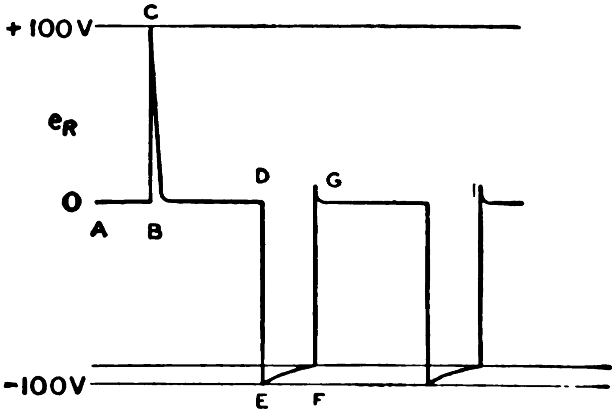


Figure 4

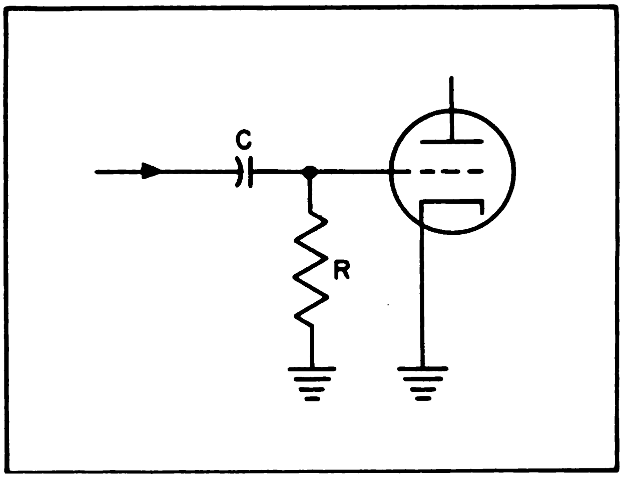


Figure 5

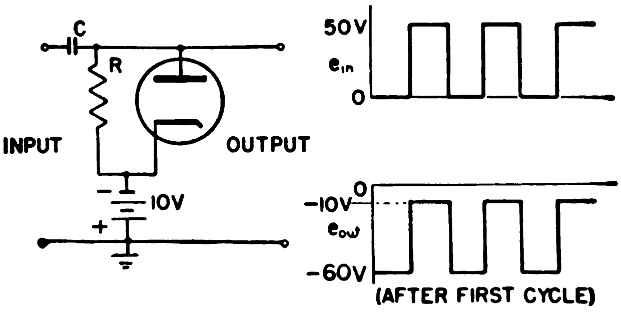


Figure 6

to the clamper, and show the effects of clamping the sweep. (This may be done by connecting the output of the clamper to the horizontal plate of the oscilloscope.)

e. Insert a bias voltage in series with the clamper circuit, and show the effects of clamping at various levels.

7. Give the class a detailed analysis of a synchronized clamping circuit.
8. Give some specific examples of applications of clamper circuits.

CONCLUSIONS

Clamping circuits are especially useful in the development of various types of cathode-ray presentations. They are used principally to prevent jitter of the picture, which would be very apparent if there were no clamping circuit to keep the sweep starting point fixed.

ORAL QUIZ

1. What is a clamping circuit?
2. What is the most important use of a clamping circuit?
3. What important advantage does the synchronized clamper have over the diode clamper?
4. Explain the action of a positive diode clamper.
5. Explain the action of grid clamping.

LESSON PLAN No. 14

SUBJECT

Introduction to square-wave generators; the Eccles-Jordan trigger circuit.

OBJECTIVE

To demonstrate the properties and applications of square waves, and the operation of the Eccles-Jordan trigger circuit.

MATERIAL REQUIRED

1. Eccles-Jordan Trigger Circuit Demonstration Unit.

2. Power Supply Demonstration Unit.

3. Single-Swing Blocking Oscillator Demonstration Unit.

4. Five-inch cathode-ray oscilloscope.

5. Vacuum-tube voltmeter.

INTRODUCTION

The multivibrator is a form of relaxation oscillator. It is used to generate the square waves essential to radar systems. The Eccles-Jordan trigger generator, with the application of two trigger pulses to its input, provides one complete cycle of square-wave output.

SUBJECT MATERIAL

1. Review, briefly, the operation of triodes and R-C circuits.

2. Draw a diagram for, and describe the operation of, the Eccles-Jordan circuit.

a. Carry the explanation of the cycle of operation from the instant B+ and filament voltages are applied until a stable operating condition exists.

b. Explain in detail the function of each circuit component in establishing stable equilibrium.

c. Trace the effect on the circuit of a trigger pulse applied to the input.

(1) Explain why positive or negative pulses may be applied to the input.

(2) Draw and analyze output waveforms appearing at both plates of the multivibrator; be sure to emphasize the phase relationship of the two waveforms.

(3) Draw and analyze the waveforms appearing at the grids of the tubes.

d. Trace the effect on the circuit of a second trigger pulse applied to the input. During this explanation, show the completion of the grid and plate waveforms for both tubes.

e. Redraw the composite output waveform for the complete cycle of operation, and analyze it again in review.

f. At this point it will be well to make a detailed explanation of some of the terms and expressions used in the above analysis. For example, a statement like "This makes the grid of V_1 positive," requires more explanation. The student will wish to know how the grid of V_1 becomes positive, as well as how far it is driven positive.

Compare what actually happens in the grid circuit with what you would expect, from your study of R-C circuits.

g. Ask the class why the simple Eccles-Jordan trigger circuit, as described, is impractical. After accepting a discussion from the class, an explanation of this point should be given.

3. Set up the Eccles-Jordan Trigger Circuit Demonstration Unit, employing the Single-Swing Blocking Oscillator Demonstration Unit to trigger it; connect the oscilloscope so that the circuit waveforms may be observed. Using the v.t.v.m., measure the plate and grid voltages of V1A and V1B.

a. Trigger the circuit to its other stable state, and measure the electrode voltages of V1A and V1B again.

b. Discuss the circuit operation qualitatively, in terms of the voltage readings.

c. Explain that the triggering sensitivity is determined by the difference in the values of the grid resistors, R5 and R6; when these values are equal, minimum triggering voltage is required.

d. Discuss the effect of changes in the values of the R-C components in the grid circuits on the shape of the output waveforms.

CONCLUSIONS

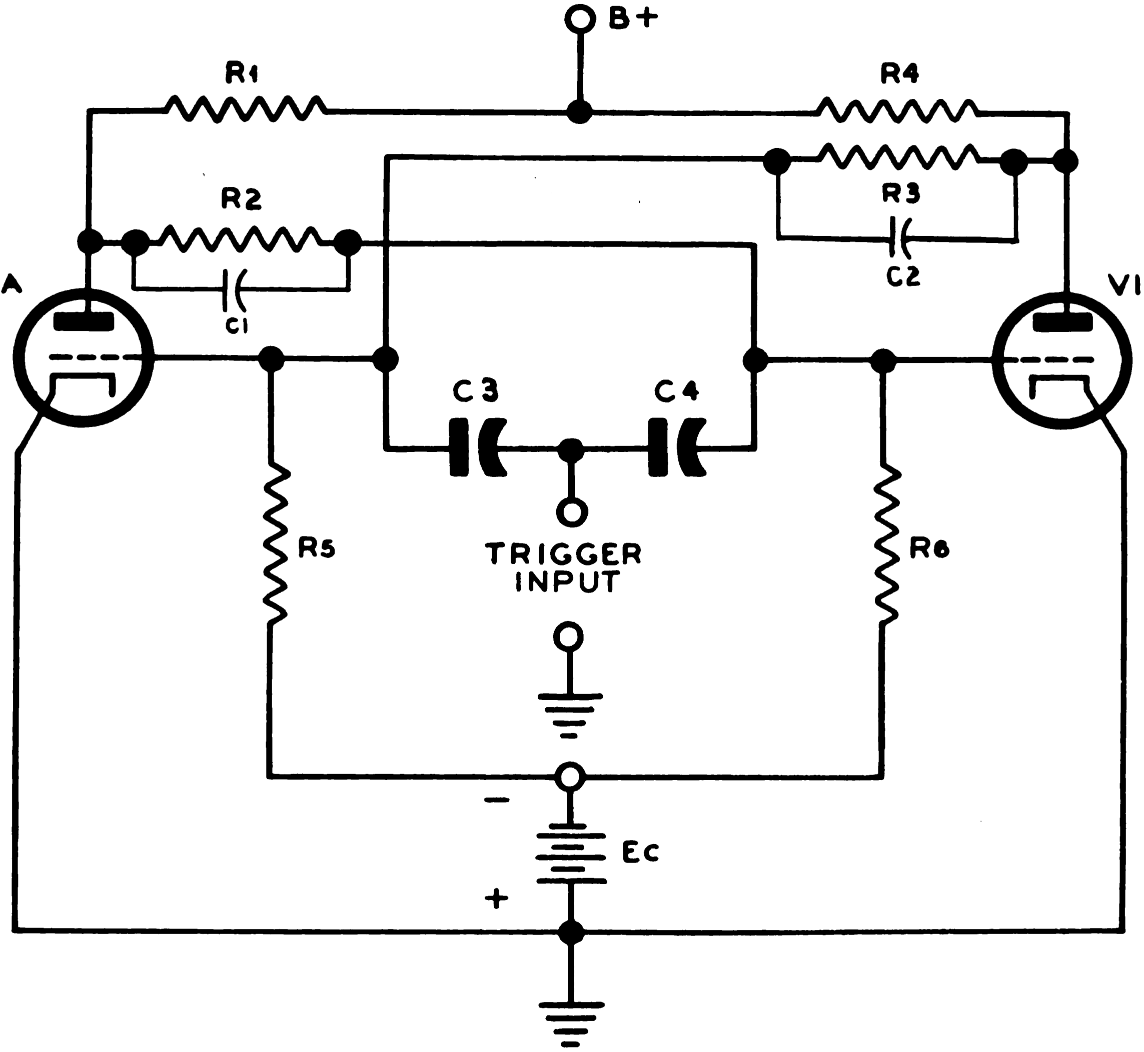
The Eccles-Jordan trigger circuit is actually a lead-up to a later discussion on multivibrators. Several other basic circuits have been employed, but the Eccles-Jordan circuit is the oldest basic design, and is widely used at present. Like the Wheatstone bridge, it may be regarded as a prototype and as a very rich source of ideas for the development of other circuits.

ORAL QUIZ

1. Explain what is meant by a "bi-stable" circuit.

2. What type of oscillator is the Eccles-Jordan multivibrator?

3. Draw the waveforms that appear at the plates of the Eccles-Jordan multivibrator when two successive trigger voltages are applied.



Eccles-Jordan Trigger Circuit

LESSON PLAN No. 15

SUBJECT

One-shot multivibrator and cathode-coupled multivibrator circuits.

OBJECTIVE

To explain the theory and operation of the one-shot multivibrator and the cathode-coupled multivibrator with respect to their applications in radar systems.

MATERIAL REQUIRED

1. One-Shot Multivibrator Demonstration Unit.
2. Cathode-Coupled Multivibrator Demonstration Unit.
3. Power Supply Demonstration Unit.
4. Single-Swing Blocking Oscillator Demonstration Unit.
5. Five-inch cathode-ray oscilloscope.

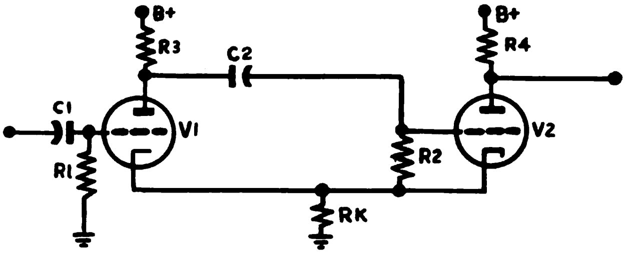


Figure 1

INTRODUCTION

The Eccles-Jordan trigger circuit and the various free-running multivibrators have been discussed in previous lessons. Hybrid combinations of a trigger circuit and a multivibrator are also of interest. In the one-shot multivibrator, the circuit returns automatically to its initial operating condition after executing one complete cycle of operation when triggered by an external pulse.

Since the plate current of a standard multivibrator is practically the same as the cathode current, an approximately rectangular output voltage may be obtained by using common-cathode-resistor coupling. The output of a cathode-coupled multivibrator is useful for determining the response of amplifiers, for the electronic switching of cathode-ray-tube patterns, and for driving differentiators as pulse makers.

SUBJECT MATERIAL

1. Draw the one-shot multivibrator circuit, and describe, in detail, the circuit action after plate and filament voltages are applied, Figure 1, 2.

a. Trace the effect of a trigger pulse on the steady-state condition of the multivibrator circuit; using a step-by-step method of presentation, show the grid and output waveforms over a complete cycle of operation.

b. The action of the R-C grid circuit in obtaining proper operating bias along with cathode resistor R_k, should be emphasized to the class.

c. Explain how changes in the values of both coupling capacitors C1 and C2, and the grid-leak resistors, R1 and R2, effect the length of the output pulses produced.

d. The response of the multivibrator to trigger pulses of any frequency should be discussed.

2. Draw the revisions necessary to make the one-shot multivibrator into the one-shot multivibrator with positive grid return, Figure 3.

a. Describe in detail the circuit action in attaining its steady-state condition, after plate and filament voltages have been applied.

b. Trace, step-by-step, the effect of a trigger pulse on the circuit for a complete cycle of operation.

c. The improved stability of the one-shot multivibrator with positive grid return can be clearly explained and illustrated, using the comparative waveform analysis of the grid in the one-shot multivibrator with grid returned to the plate-supply source.

3. The Power Supply Demonstration Unit should be set up with the One-Shot Multivibrator Demonstration Unit in conjunction with the Single-Swing Blocking Oscillator Demonstration Unit and the five-inch cathode-ray oscilloscope, to illustrate the circuit action as described theoretically in paragraph 1.

4. Substitute the Cathode-Coupled Multivibrator Demonstration Unit for the One-Shot Multivibrator Demonstration Unit, as given in paragraph 3, and show (and give a review explanation of the cathode-coupled multivibrator operation) the circuit waveforms on the cathode-ray oscilloscope. Perform the demonstration with and without synchronizations.

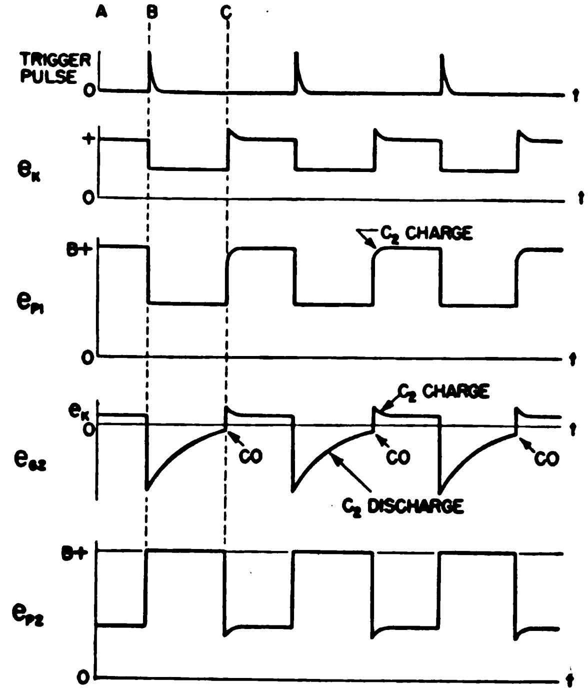


Figure 2

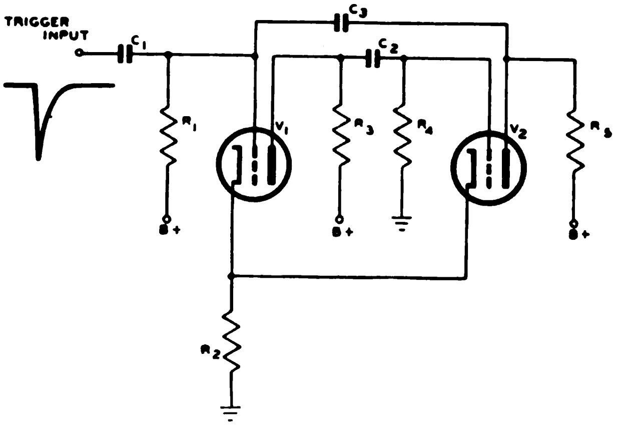


Figure 3

CONCLUSIONS

The one-shot multivibrator is used to control the duration of the sweep in a radar system because it is capable of generating a pulse of exactly the proper duration at a rate determined by the pulse from the timer. It can never get out of synchronism, since it does not put out any signal until it is triggered.

Cathode-coupled unbalanced multivibrators can furnish short, sharp, and approximately rectangular pulses that are particularly useful in the operation of keying tubes.

ORAL QUIZ

1. Explain the difference between the Eccles-Jordan trigger circuit and the one-shot multivibrator.

2. Explain the difference in the action of the one-shot multivibrator with grid returned to the cathode, and to the plate-supply source.

3. How does the cathode-coupled multivibrator establish its free-running state?

4. State several advantages of the cathode-coupled multivibrator.

LESSON PLAN No. 16

SUBJECT

Plate-coupled multivibrator; synchronization of multivibrators; electron-coupled multivibrator.

OBJECTIVE

To explain the theory and operation of the plate-coupled and electron-coupled multivibrator, and to present the concept of multivibrator synchronization.

MATERIAL REQUIRED

1. Power Supply Demonstration Unit.
2. Single-Swing Blocking Oscillator Demonstration Unit.
3. Plate-Coupled Multivibrator Demonstration Unit.
4. Five-inch cathode-ray oscilloscope.
5. Vacuum-tube voltmeter.

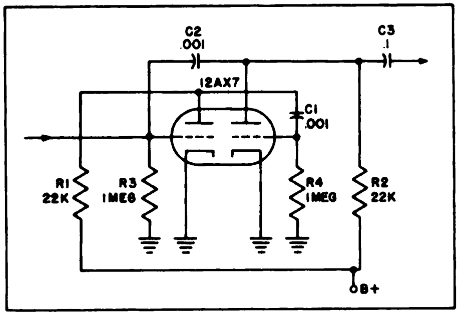


Figure 1. Plate Coupled Multivibrator

INTRODUCTION

A multivibrator circuit is essentially a two-stage resistance-capacitance-coupled amplifier with the output fed back to the input. The plate-coupled multivibrator is an example of the basic free-running type multivibrator. Its output waveform is rectangular, and is usable in the radar system as a timing and gating voltage.

Since variations in plate load will cause instability of operation in a multivibrator, the triodes are sometimes replaced by pentodes, with the necessary coupling accomplished in the screen-grid circuit.

Multivibrators may be synchronized by coupling a sinusoidal or pulse voltage to any electrode in the tube. The frequency of the synchronizing voltage may be the same as, a multiple of, or a submultiple of, the natural frequency of the multivibrator.

SUBJECT MATERIAL

1. Draw the basic free-running symmetrical multivibrator circuit, and present a detailed account of the circuit action for two complete cycles of operation, Figure 1.

a. Incorporate in the explanation, wherever applicable, a few words in review of R-C circuit theory and the characteristics of vacuum tube amplifier circuits under conditions of cutoff and conduction.

b. During the explanation, the multivibrator grid and output waveforms should be carefully drawn and explained, Figure 2.

(1) Point out that the circuit action taking place, from the time the B+ and filament voltages are applied to the time when one tube is completely cut off, occurs almost instantly. This is represented by the vertical lines at the beginning of each cycle.

(2) The R-C circuit involved in the study of the action at the grid of V1 consists of more than just C1 and R1. The grid-to-cathode resistance of the tube is in parallel with R1. The fact that this resistance is usually much lower than R1 whenever the grid is positive, and not much higher than R1 when the grid is negative, accounts for the waveform.

c. The effect of variations in the R-C grid circuit parameters upon frequency and symmetry should be discussed.

(1) Show the effect of changing both R1 and C1.

(2) Show the effect that non-symmetrical R-C components have upon output waveforms.

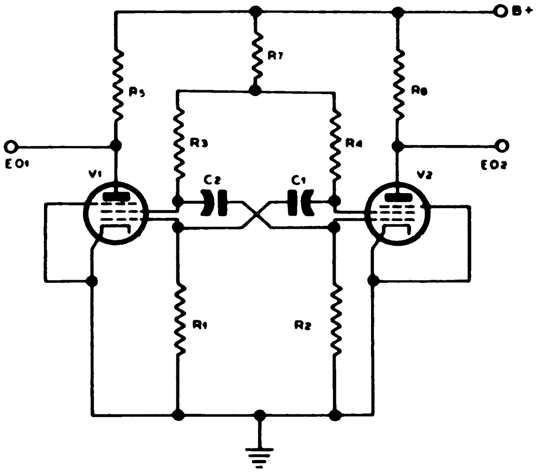
d. Increased stability or frequency control may be obtained by connecting one or both grid resistors to a high positive bias source, instead of connecting them to the grounded cathode (as in the conventional multivibrator circuit). This causes the graph of the grid potential variation to intersect the cutoff line with a steeper slope than would otherwise be obtained, thus improving the accuracy of timing. Give a description of the operation under this conditions; show the resultant waveforms.

2. Set up the Plate-Coupled Multivibrator Demonstration Unit, and review its circuit action by observing grid and plate waveforms by means of the oscilloscope. Measure grid and plate voltages.

3. Present the electron-coupled multivibrator circuit; give the class a step-by-step explanation of two complete cycles of operation.

a. During the operation, briefly review pentode characteristics.

b. Since the electron-coupled multivibrator is used where variations in plate loading would affect stability of operation, emphasis should be placed on the fact that the plate circuits of the multivibrator tubes only provide a means of obtaining output waveforms and do not enter into the circuit operation. Explain to the class that plate circuit load variations have no effect upon frequency stability.



Electron Coupled Multivibrator Circuit

c. Variations in values of the grid circuit R-C components will affect the output frequency. Explain this.

4. Revise the basic free-running multivibrator circuit to one with pulse type synchronizing voltage applied to the cathode by inserting a pulse generator in the grid-to-cathode circuit.

a. Trace the effect of applying a positive pulse from the generator to the non-conducting tube.

(1) Illustrate, by using the waveform of synchronized grid voltage, how the cycle of the multivibrator is shortened by the applied pulse.

(2) Explain why the period of the multivibrator must be greater than the interval between trigger pulses, to insure proper synchronization.

b. Explain the effect on the frequency of the multivibrator when it is synchronized to a submultiple of the trigger frequency.

c. Trace the effect of applying a negative pulse to the conducting tube of the multivibrator.

d. Emphasis should be placed on the pulse polarity necessary to control the conducting and non-conducting tubes.

5. Set up the Single-Swing Blocking Oscillator Demonstration Unit in conjunction with the setup given in paragraph 2 for the plate-coupled multivibrator, and demonstrate the principle of synchronization as a review to the student.

CONCLUSIONS

Multivibrators are relaxation oscillators, and are used in many forms in electronic systems. Though the free-running multivibrator has a natural frequency of its own, and will operate without any assistance from external sources, a fine control of the operating frequency may be secured by synchronization.

ORAL QUIZ

1. Referring to the basic free-running multivibrator circuit, complete the following sentences by inserting the correct word: (1)

a. Decrease R3 to_______frequency.

b. _______C2 to increase frequency.

c. Decrease the plate resistance, Rp, of the tube to_______frequency.

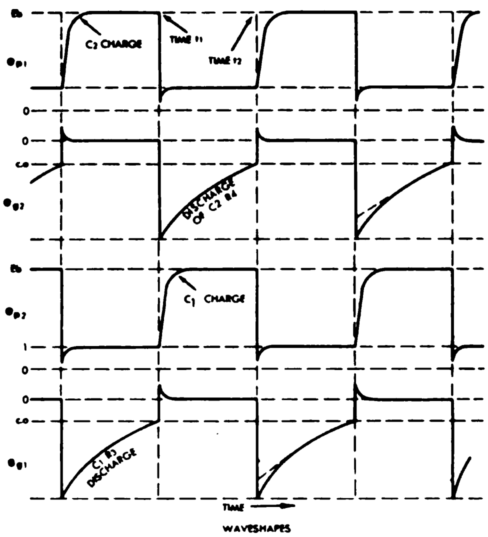


Figure 2

d. As the ratio of R3/Rp approaches_______, distortion increases.

2. In the basic free-running multivibrator circuit, an increased plate current through V1A increased the voltage drop across R1, this decreasing the voltage at the plate of V1A. Capacitor C1 couples this drop in plate voltage to the grid of V1B as a negative voltage. Explain.

3. How should an increase in B+ of a plate-coupled multivibrator affect its frequency stability?

4. What is the function of the suppressor grids in the electron-coupled multivibrator?

5. How is frequency division accomplished in a multivibrator?

EXAMINATION No. 4

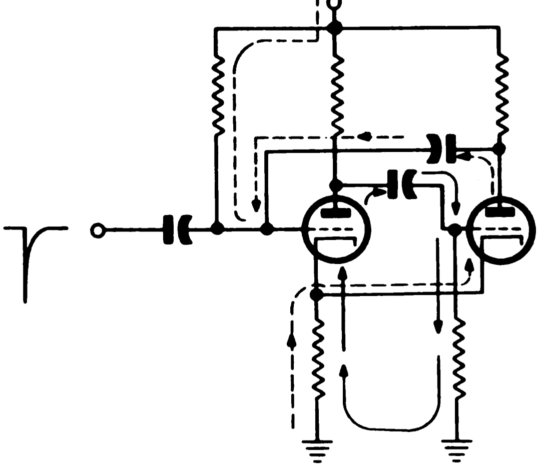
1. c . Another name given to the Eccles-Jordan multivibrator is:
   a. Free-running multivibrator.
   b. Self-flopping circuit.
   c. Flip-flop circuit.
   d. Squegging oscillator.
   e. Phase-reversing oscillator.

2. c . The Eccles-Jordan multivibrator:
   a. Requires two trigger pulses to complete a cycle of operation.
   b. Requires a positive pulse to complete a cycle of operation.
   c. Requires two trigger pulses to complete a cycle of operation.
   d. Can be operated free-running or synchronized.
   e. Is a single-kick multivibrator.

3. c . The most desirable waveform for synchronizing a multivibrator is:
   a. A sine wave.
   b. A pulse with a sharp trailing edge.
   c. A pulse with a sharp leading edge.
   d. A triangular pulse.

4. c . The main advantage of using the waveform given in question 3 is:
   a. It is easy to generate.
   b. Timing changes as pulse amplitude changes.
   c. Timing does not change as pulse amplitude changes.
   d. The leading edge of the waveform is unimportant.

5. Draw the circuit of a positive-grid-return, one-shot multivibrator, and indicate, by means of arrows, the discharge path of either plate-to-grid coupling capacitor.



Suggested Drawing

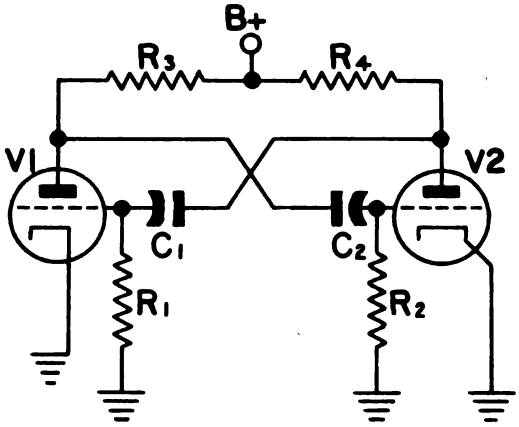


Figure 1

6. b . In the one-shot multivibrator, the maximum plate current of V2 is:
   a. Equal to maximum Ip of V1.
   b. Greater than Ip maximum of V1.
   c. Less than maximum Ip of V1.
   d. None of the above is correct.

7. d . The cathode-coupled multivibrator:
   a. Is also known as a one-shot multivibrator.
   b. Uses a cathode resistor to maintain one tube always at cutoff, until it is triggered by an external sync pulse.
   c. Has one grid returned to the cathodes.
   d. Has equal bias voltages on the two cathodes.

8. c . The cathode-coupled multivibrator which uses capacitive coupling:
   a. Is also known as a one-shot multivibrator.
   b. Uses a cathode resistor to maintain one tube always at cutoff until it is triggered by an external sync pulse.
   c. Has both grid resistors returned to ground.
   d. Always has equal bias voltages on the two cathodes.

9. c . The electron-coupled multivibrator:
   a. Utilizes coupling through the electron streams of two tubes, instead of R-C coupling.
   b. Has poor stability, even with light loading of the output circuit.
   c. Has good frequency stability as its main advantage.
   d. Uses only one pentode, with oscillator coupling through the stream.

10. d. In figure 1, the approximate frequency of operation is determined by:
- a. R1 and R2.
- b. R3 and R4.
- c. C1 and C2.
- d. R1, C1 and R2, C2.
- e. The plate resistance of the tubes.

11. c. In figure 1, the components in the discharge path of C1 are:
- a. R2, C2 and V1.
- b. R1, R4, B+, and the grid circuit of V1.
- c. R1 and V2.
- d. V1, R3, and R4.

12. a. In figure 1, the charge path of C2 includes the following components:
- a. R2, the grid circuit of V2, R3, and B+.
- b. R2 and V1.
- c. R4, R3, V1, and C1.
- d. V1, V2, R4, and B+.

13. b. In figure 1, increasing R1 would:
- a. Increase the conducting time per cycle of V1.
- b. Increase the cutoff time per cycle of V1.
- c. Decrease the conducting time per cycle of V1.
- d. Decrease the cutoff time per cycle of V1.

14. a. In figure 1, decreasing R1 or R2 would:
- a. Increase the frequency of operation.
- b. Decrease the frequency of operation.
- c. Not affect the frequency of operation.

15. c. If a sine wave is applied to a short time constant R-C circuit, the signal across the resistor will be in the form of:
- a. A square wave.
- b. A peaked wave.
- c. A phase-shifted sine wave.

16. c. Multivibrator circuits which are to be synchronized *require* that the sync pulse be:
- a. Introduced into the cut-off tube.
- b. Introduced into the conducting tube.
- c. Negative, if coupled into the conducting tube.
- d. Both b and c are correct.

17. c. A sync signal coupled into a multivibrator:

a. Controls the time duration of each of the pulse alternations.

b. Controls the output frequency of the multivibrator, being slightly lower in frequency than the natural operating frequency of the multivibrator.

c. Controls the output frequency of the multivibrator, being generally higher in frequency than the natural frequency of the multivibrator.

d. Controls the output frequency of the multivibrator by regulating the RC time constants of the circuit.

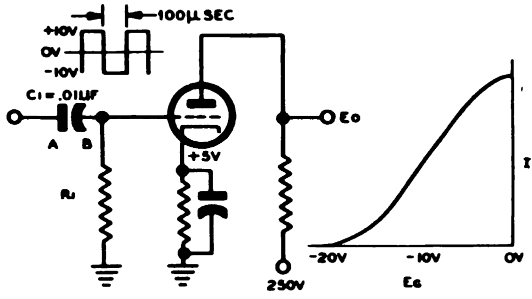


Figure 2

18. Referring to figure 2, draw the waveform at the grid of the tube.

19. c. In figure 2, the capacitor will charge to:
- a. 10 volts.
- b. Zero volts.
- c. 5 volts.
- d. 15 volts.

20. c. A positive clamping circuit can be used to:

a. Cause a wave to remain positive with respect to zero by removing the negative peaks.

b. Establish a reference level of zero by introducing amplitude distortion.

c. Add enough d-c component to a waveform so that it never goes below zero.

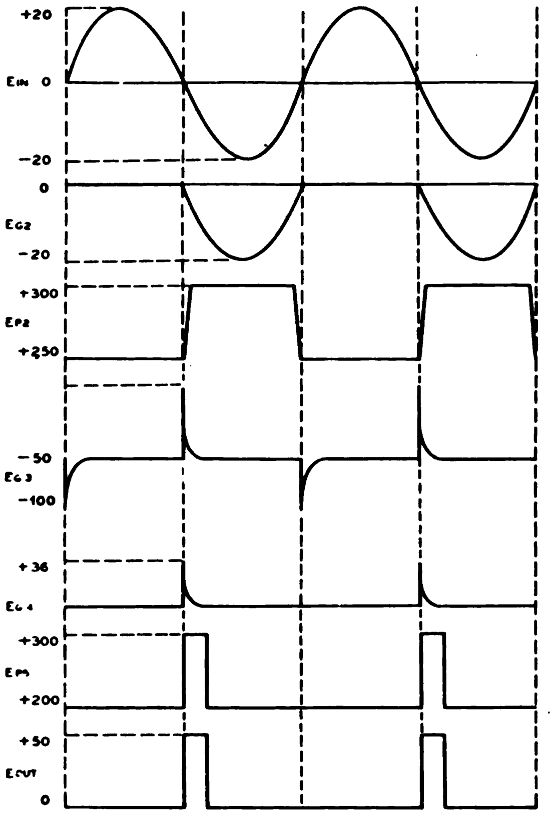
21. b. The V4, V5 circuit of figure 3, is a:
- a. Cathode-coupled multivibrator.
- b. One-shot multivibrator.
- c. Plate-coupled multivibrator.
- d. Triggered plate-coupled multivibrator.

Answers to 22, 23, and 24 are to be drawn as a synchrogram on page 51.

22. Draw the waveform for the grid and plate of V2 and indicate voltages.

23. Draw the waveform for the grid of V3 and the grid of V4, and indicate voltages.

24. Draw the waveform at the plate of V5, and the output waveform, and indicate voltages.



Suggested Drawing For Questions 22, 23, and 24

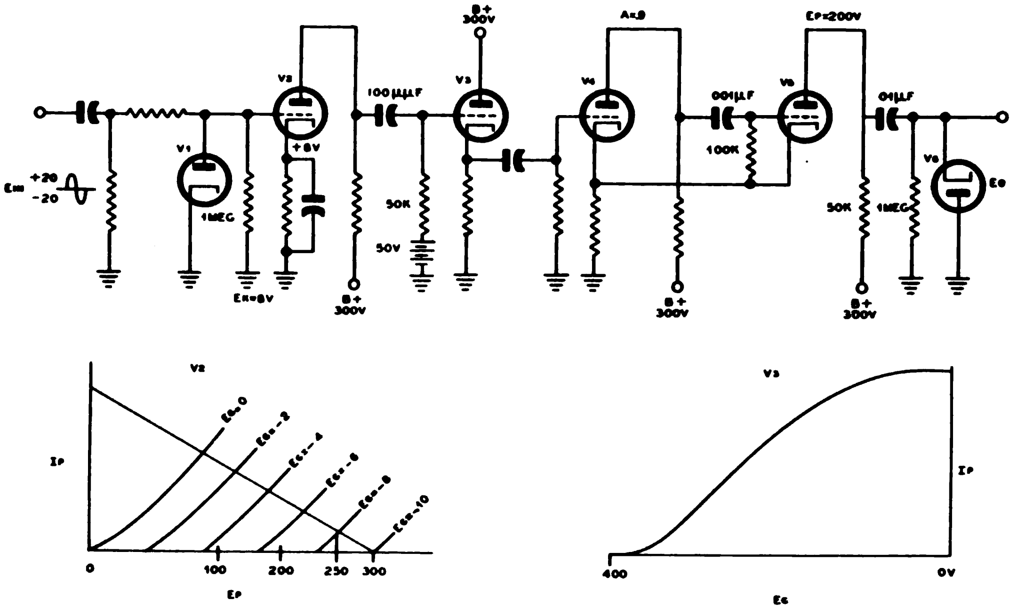


Figure 3

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LESSON PLAN No. 17

SUBJECT

Phantastrons.

OBJECTIVE

To explain the theory of operation of the phantastron delay circuit.

MATERIAL REQUIRED

1. Power Supply Demonstration Unit.
2. Phantastron Demonstration Unit.
3. Five-inch cathode-ray oscilloscope.
4. Single-Swing Blocking Oscillator Demonstration Unit.

INTRODUCTION

The phantastron delay circuit, producing at its output a square waveform, employs a single pentagrid tube instead of the double triode necessary in the conventional type of multivibrator.

SUBJECT MATERIAL

1. Use the Phantastron Delay Circuit INFORMATION SHEET during this lesson.

2. Draw the phantastron circuit on the blackboard.

3. Explain thoroughly the function of each element of the pentagrid tube in the circuit, emphasizing the following:

a. The double triode similarity to the pentagrid as shown.

b. The control of the division of current between plate and screen.

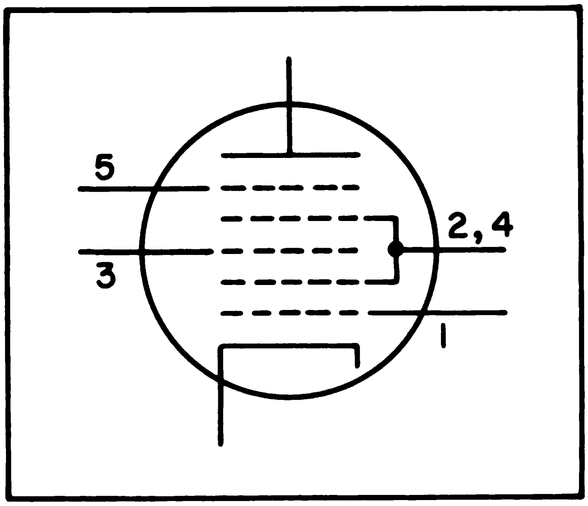
c. The static operating characteristics of the tube.

4. Give a step-by-step analysis of the circuit action, from the instant B+ and filament voltages are applied until a steady-state condition is reached.

Explain the normally "on" and "off" conditions existing in the different sections of the pentagrid tube.

5. Trace the effect of the application of a positive trigger pulse upon the circuit for a complete cycle of operation, using a step-by-step explanation.

a. Carefully draw and discuss the waveforms of the basic phantastron delay circuit, and compare them with those of the cathode-coupled multivibrator.



Pentagrid Tube for the Phantastron Circuit

b. Emphasize the switching process of the circuit, and discuss its limitations.

c. Show where an output is obtained from the phantastron circuit.

d. Discuss the effect on the grid and output waveforms produced by variations in the components of the R-C grid circuits.

6. Set up the Power Supply Demonstration Unit, in conjunction with the Single-Swing Blocking Oscillator Demonstration Unit, the Phantastron Demonstration Unit, and the oscilloscope.

a. In review, explain the theory and operation of the phantastron delay circuit as the visual demonstration proceeds; call attention to the similarity to the one-shot multivibrator.

b. Observe all grid and output waveforms on the oscilloscope.

(1) Compare them with the theoretically anticipated waveforms.

(2) Explain and justify any discrepancies.

c. Suggest some practical uses for the phantastron circuit.

CONCLUSIONS

Whereas the multivibrator establishes an exponential timing waveform, phantastron-type circuits generate a linear timing waveform. This leads to a very important advantage—the duration of the output rectangle can be made a linear function of an input control voltage.

ORAL QUIZ

1. Explain the difference between the phantastron and:
   a. The one-shot multivibrator.
   b. The cathode-coupled multivibrator.
2. Explain the switching process, as accomplished by the phantastron.
3. Why should the plate voltage dropping resistor, be large in value?

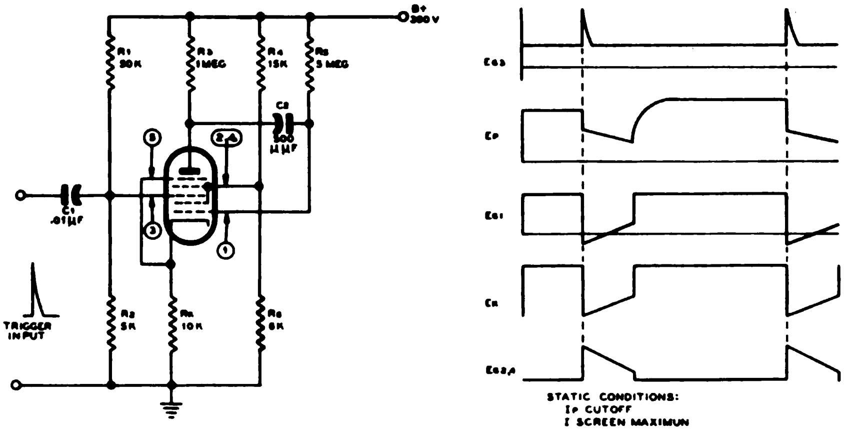
INFORMATION SHEET

PHANTASTRON DELAY CIRCUIT

1. A positive trigger pulse is applied to grid No. 3.
2. Plate current (I_p) starts to flow, causing plate voltage (E_p) to decrease sharply.
3. The change in plate voltage is coupled to grid No. 1 through capacitor C2, thus driving the grid negative.
4. The negative grid No. 1 reduces the current flow through the whole tube, reducing the voltage drop across R_k.
5. Less positive voltage on the cathode makes grid No. 3 to cathode voltage more positive, increasing I_p.
6. Since grid No. 3 controls the division of current between plate and screen (grids No. 2 and No. 4), the increase in I_p is accompanied by a decrease in the screen current.
7. After the initial sharp increase in I_p, and decrease in I_{sc}, both I_p and I_{sc} increase slowly.
8. At the same time I_p is increasing and E_p is decreasing, C2 is discharging through R5, causing the voltage at grid No. 1 to rise slowly.
9. The increasing current through the tube causes an increasing voltage drop across R_k, and this voltage eventually reaches a point where the grid No. 3 to cathode voltage reaches I_p cutoff.
10. Plate current ceases to flow and screen current goes quickly to maximum. The plate voltage rises to B+ exponentially as C2 takes on its charge through R3. Thus, the circuit returns to static conditions.

ADVANTAGE OF CIRCUIT

The advantage of the phantastron over similar types of circuits is that the relationship between the output pulse duration and the value of control voltages is very nearly linear. One method of controlling pulse duration would be to make the B+ potential variable. A decrease in B+ would result in a reduction of output-pulse duration.



STATIC CONDITIONS:
Ip CUTOFF
I SCREEN MAXIMUN

Phantastron Delay Circuit

LESSON PLAN No. 18

SUBJECT

Self-pulsing blocking oscillators.

OBJECTIVE

To teach the operating theory of, and to give applications of, self-pulsing blocking oscillators.

MATERIAL REQUIRED

1. Self-Pulsing Blocking Oscillator Demonstration Unit.
2. Five-inch cathode-ray oscilloscope.
3. Power Supply Demonstration Unit.

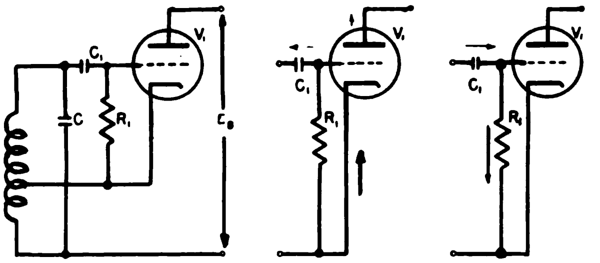


Figure 1

INTRODUCTION

Nearly all radar transmitters are pulsed, that is, made to operate in a series of short bursts of high r-f power. In general, two methods of pulsing are possible: in the first method, a separate timing circuit pulses the transmitter; in the second method, the oscillator pulses itself by developing a grid bias voltage that keeps the tubes cut off except during the short pulse periods. The self-pulsing type of blocking oscillator, which is an example of the second method, is biased to cutoff after several cycles of oscillation. The pulse repetition frequency is determined by the RC time constant of the grid capacitor and resistor.

SUBJECT MATERIAL

1. Give the class a brief review of the conventional Hartley oscillator, Figure 1.

a. Point out the frequency-determining components, and explain how changes in the tank capacitor and inductance affect the r-f output frequency.

b. Review the parallel-resonance formula

$$F = \frac{1}{2\pi\sqrt{LC}}$$

2. Draw, and explain in detail, the build-up of bias voltage and amplitude of oscillations to a limiting value in a conventional oscillator, Figure 2.

3. Set up the Self-Pulsing Blocking Oscillator Demonstration Unit. Operate the oscillator as a conventional Hartley oscillator, by decreasing R1 to minimum value. Point out continuous oscillation, as viewed on the oscilloscope.

4. Explain the effects of increasing R_{GL} on the build-up of grid bias voltage to cutoff, so that pulsing occurs, Figure 3.

Draw the intermittent pulses of r-f energy produced by self-pulsing action, and the change in grid bias caused by the self-pulsing action.

5. Explain the distinction between the frequency of the r-f energy in the pulse and the pulse recurrence frequency.

6. Explain the effect of the grid capacitor value upon both pulse width and pulse recurrence frequency.

7. Explain the effect of the grid-resistor value upon pulse recurrence frequency.

8. Using the Self-Pulsing Blocking Oscillator Demonstration Unit as set up in paragraph 3, obtain continuous r-f output. Increase R1 until pulsing occurs. Vary R1 to obtain different pulse-recurrence frequencies.

9. Change the value of C2 to obtain several different pulse widths and repetition rates. Emphasize the effect of the capacitor upon both pulse width and pulse recurrence frequency.

10. Draw the circuit diagram of a self-pulsed oscillator, with r-f components omitted. Draw the synchronizing pulse obtained across R_k, and discuss the effect of C_k in by-passing r-f components of plate current. Explain briefly the use of the synchronizing pulse obtained, Figure 4.

11. Discuss sine-wave synchronization of the self-pulsed oscillator, Figure 5.

a. Discuss the need for synchronization of self-pulsed oscillators.

b. Draw the grid-voltage waveform of the synchronized self-pulsed oscillator.

12. Discuss the advantage of the self-pulsed blocking oscillator.

It is simple, requiring no auxiliary modulation equipment.

13. Discuss the disadvantages of the self-pulsed oscillator.

a. Pulse recurrence rate may vary unless oscillator is synchronized.

b. There is a possibility of continuous-wave operation, causing average plate current to increase from milliamperes to amperes, since pulse width is of the order of one-thousandth of the resting time, in actual practice.

Discuss possible causes of continuous-wave operation.

CONCLUSIONS

The use of a self-pulsed blocking oscillator is a relatively simple method of obtaining pulses of r-f energy. Increasing the value of the grid capacitor increases the pulse width and decreases the pulse recurrence rate.

ORAL QUIZ

1. What is the distinction between the r-f output frequency and the pulse recurrence frequency obtained from a self-pulsing blocking oscillator?

2. For this question use the Self-Pulsing Blocking Oscillator Demonstration Unit.

a. What are the r-f frequency-determining components?

b. What are the pulse-recurrence frequency-determining components?

c. What is the pulse-width-determining component?

3. What is the effect of an increase in the value of grid resistance?

4. What is the effect of an increase in the value of the grid capacitor upon:

a. Pulse width?

b. Pulse recurrence frequency?

5. What is the effect of a change in the value of the grid capacitor upon r-f output frequency?

6. What is the effect of a change in the value of the grid resistor upon r-f requency?

7. What is the effect of an increase in the value of the tank capacitor upon:

a. R-F frequency?

b. Pulse recurrence frequency?

c. Pulse width?

8. What might cause a self-blocking oscillator to operate as a continuous-wave oscillator? What is the danger of such occurrence in a radar transmitter?

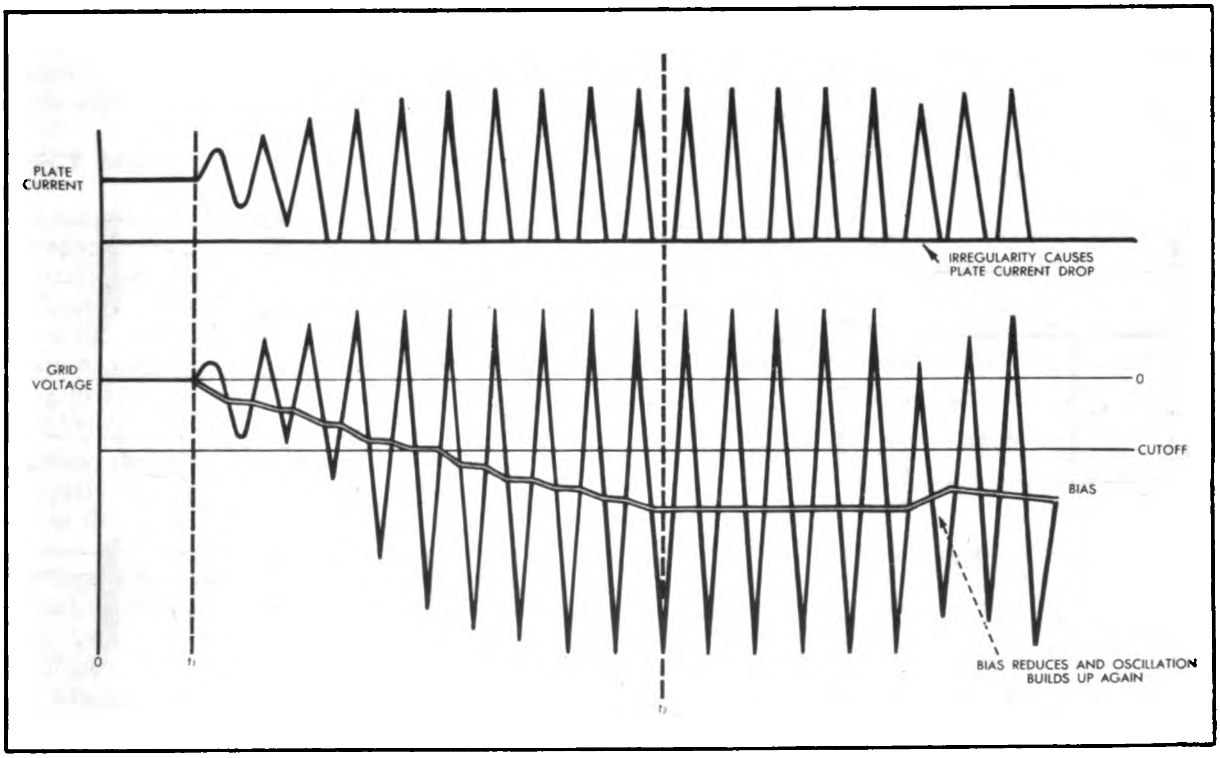


PLATE CURRENT
IRREGULARITY CAUSES PLATE CURRENT DROP
GRID VOLTAGE
0
CUTOFF
BIAS
0
t1
t2
BIAS REDUCES AND OSCILLATION BUILDS UP AGAIN

Figure 2

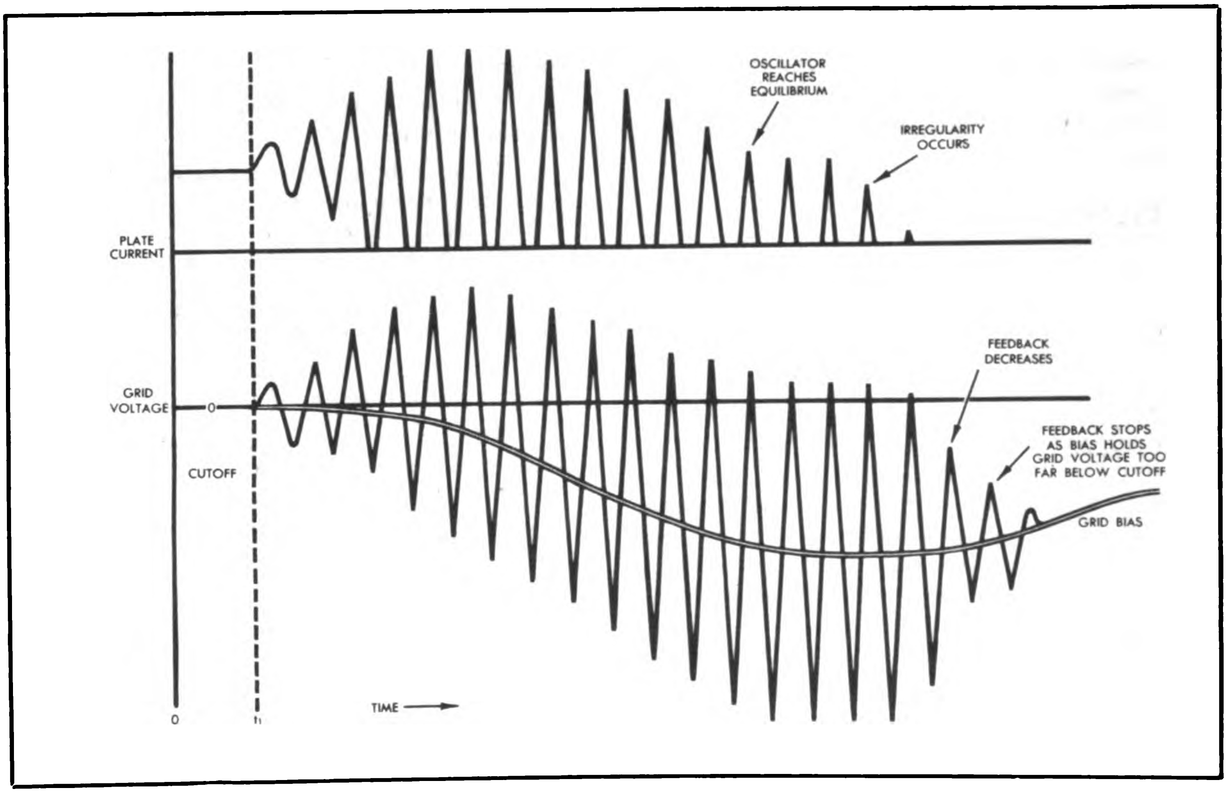


Figure 3

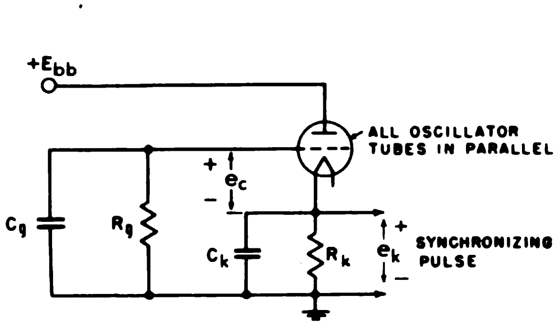
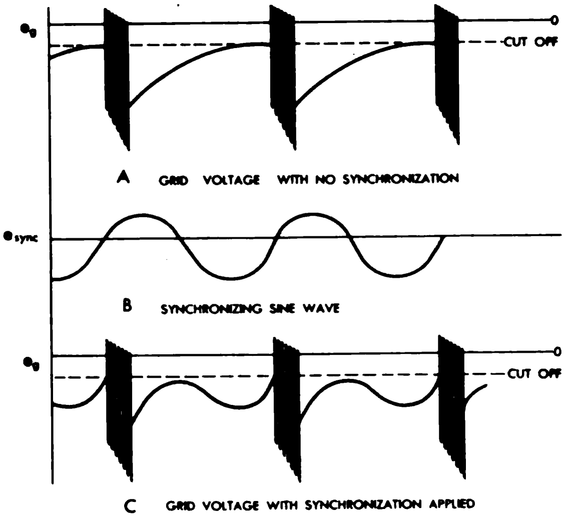


Figure 4



A GRID VOLTAGE WITH NO SYNCHRONIZATION

B SYNCHRONIZING SINE WAVE

C GRID VOLTAGE WITH SYNCHRONIZATION APPLIED

Figure 5

LESSON PLAN No. 19

SUBJECT

Shock-excited oscillators.

OBJECTIVE

To explain the theory and operation of shock-excited oscillators.

MATERIAL REQUIRED

1. Shock-Excited Oscillator Demonstration Unit.
2. Five-inch cathode-ray oscilloscope.
3. Power Supply Demonstration Unit.
4. Single-Swing Blocking Oscillator Demonstration Unit.
5. One-Shot Multivibrator Demonstration Unit.

INTRODUCTION

The shock-excited oscillator is used to produce range markers on a radar oscilloscope screen. In this circuit, a vacuum tube acts as a switch to interrupt the steady flow of plate current through the inductance section of an L-C tank circuit which produces damped sinusoidal oscillations. A negative, square-shaped pulse of predetermined width is used to periodically cut off the tube.

SUBJECT MATERIAL

1. Review transients in a parallel R-L-C circuit by drawing and discussing voltage waveforms for underdamping, critical damping and overdamping. Discuss frequency of oscillation, and the effect of the circuit Q upon damping. (As a preliminary to ringing oscillators, a discussion concerning losses in the series resistance of the coil will be beneficial.)

2. Draw the shock-excited oscillator circuit, and explain the operation of the ringing circuit, showing the similarity of this circuit to the one discussed in paragraph 1, above. See Figure 1.

a. Draw the input and output waveforms of the shock-excited oscillator, showing a period of four or five cycles of r-f oscillation to one gate pulse, Figure 2.

b. Discuss the effect of changes in the Q of the tank circuit on the damping of oscillations, and point out the necessity for a high tank circuit Q.

c. Explain the overdamping effects that the tube offers to the L-C circuit when the gate pulses swing positive and the tube conducts.

d. Set up the Single-Swing Blocking Oscillator Demonstration Unit and the One-Shot Multivibrator Demonstration Unit to produce negative gate pulses for the Shock-Excited Oscillator Demonstration Unit. Set up the Shock-Excited Oscillator Demonstration Unit to function as a ringing oscillator.

(1) Show the gate-pulse waveforms on the oscilloscope.

(2) With R3 in the shock-excited oscillator circuit set at a minimum value, show the output waveform. Increase R3, to show its damping effect.

(3) Change the value of C1, to emphasize its effect on the frequency of oscillation.

(4) By varying the width of the gate pulse, show the change produced in the duration of oscillations.

3. Draw the shock-excited peaking-oscillator circuit, and discuss the operation of the circuit. Point out the frequency-determining action of the tank circuit. Explain the purpose of the damping resistor across the tank, Figure 3.

Draw the waveforms associated with this circuit, and discuss them. Explain why the negative-going pulse is wider than the positive-going pulse, Figure 4.

4. Change the demonstration unit setup to make the shock-excited oscillator perform as a peaking circuit. Adjust the tank circuit to the critical damping stage, and show the waveforms. Substitute values of resistance to produce overdamping and underdamping, showing the waveforms.

5. To help the students understand the functioning of the ringing and pulsing oscillators, a block diagram representation of the range-marker circuit, showing output waveforms of each stage, is advisable.

6. Discuss the limitation of the ringing oscillator because of the damping produced by the resistance of the tank coil.

7. Draw a pulsed two tube Hartley oscillator circuit, and discuss its operation.

a. Explain that this oscillator circuit becomes operative when the tube cuts off.

b. Explain the purpose of the grid resistor in the circuit.

c. Explain the rapid damping of oscillations when the tube conducts.

d. Explain the advantage of this circuit over the ringing-oscillator circuit.

CONCLUSIONS

Shock-excited oscillators are designed to produce recurrent waveform outputs when recurring negative gate pulses are applied to their inputs. Generally, there are two types of shock-excited oscillators. The first produces pulses of sine-wave oscillations, and the second produces narrow, peaked pulses. The ringing oscillator is a circuit of the first type, which has the disadvantage that the sine-wave oscillations in the pulse are damped. The two-tube pulsed Hartley oscillator overcomes this undesirable characteristic by supplying r-f energy to make up for the losses in the tank circuit, thus producing sine-wave pulses of constant amplitude.

ORAL QUIZ

1. In the diagram of the ringing oscillator, what are the frequency-determining elements?

2. In the diagram of the output waveform of the ringing oscillator, what is the cause of the damped envelope of oscillations? (Figure 2.)

What causes the oscillations to cease when the gate pulses are removed?

3. From the diagram of the shock-excited peaker, answer the following questions:

a. What does capacitor C represent?

b. What is the purpose of resistor R?

c. If the tank is resonant at 2 megacycles, and X_L is 5000 ohms, what value of R is required for critical damping? ($R = \frac{1}{2}\sqrt{L/C}$, $Q = \frac{1}{2}$.)

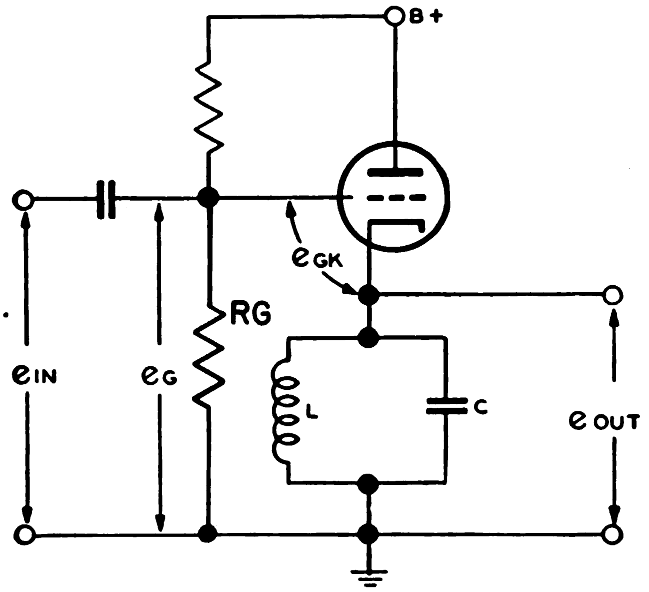


Figure 1

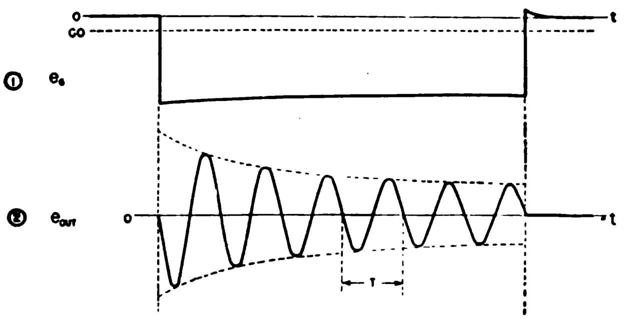


Figure 2

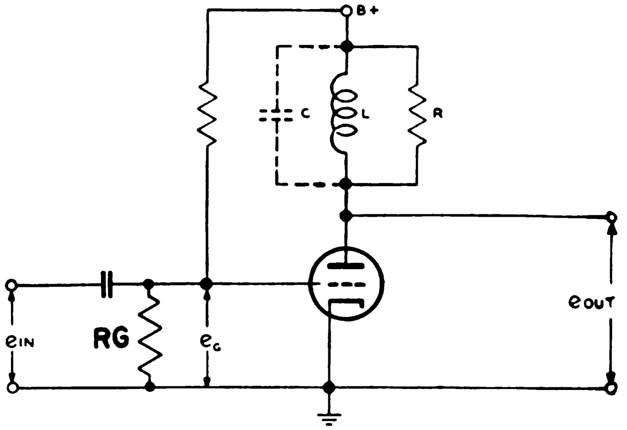


Figure 3

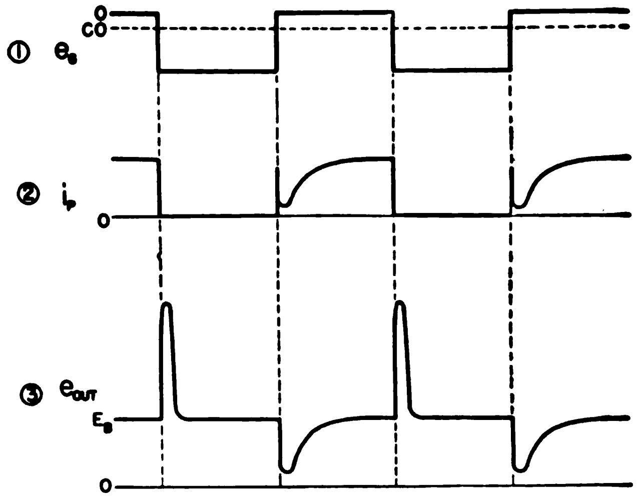


Figure 4

LESSON PLAN No. 20

SUBJECT

Single-swing blocking oscillator.

OBJECTIVE

To explain the theory of operation of the single-swing blocking oscillator circuit.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Demonstration Unit.
2. Power Supply Demonstration Unit.
3. Audio signal generator.
4. Five-inch cathode-ray oscilloscope.

INTRODUCTION

The single-swing blocking oscillator is used as a master oscillator in timing systems. Because it produces the desired narrow pulses, its construction is more simple, for this purpose, than a sine-wave oscillator with its associated wave-shaping circuits.

SUBJECT MATERIAL

1. Using a diagram of a single-swing blocking oscillator, make a step-by-step explanation of one complete cycle of operation, Figure 1.

   a. Begin the discussion at the point where the grid is at cutoff.

   b. Use waveforms to aid this discussion, Figure 2.

   c. During the discussion, explain the formation of the grid, plate, and output waveforms, and point out corresponding points on the three waveforms at plate-current saturation and at maximum negative grid voltage.

   d. Discuss the effect of the values of the grid circuit R and C upon repetition rate; point out the grid-capacitor-discharge portion of the grid-voltage waveform.

   e. Set up the Single-Swing Oscillator Demonstration Unit as an unsynchronized oscillator. Vary the repetition rate by changing the value of C1.

2. Discuss synchronization of the single-swing blocking oscillator from the point of view of an external signal at the grid stabilizing or "locking in" the pulse rate of the oscillator.

3. Set up the Single-Swing Blocking Oscillator Demonstration Unit. Apply a synchronizing signal, and show the effect it has on the pulse repetition frequency.

4. Begin discussion of the triggered-type single-swing blocking oscillator with a comparison of the free-running and the triggered-type blocking oscillator.

   a. The repetition rate of a free-running oscillator is determined by its own grid RC time constant.

   b. The repetition rate of the triggered oscillator is fixed by the repetition rate of trigger pulses applied to the grid.

   c. The circuit of a triggered oscillator is the same as that of a free-running oscillator except that high negative bias is applied to the grid to hold the tube normally in cutoff.

5. Using a circuit diagram and waveforms, describe the operation of the triggered blocking oscillator. Begin the discussion with the tube cut off, then trace the operation over a complete cycle.

6. Discuss a plate-to-cathode feedback blocking-oscillator circuit similar to that in the Step-Counting Demonstration Unit. Do not discuss the counting circuit itself.

CONCLUSIONS

Single-swing blocking oscillators produce recurring narrow, peaked pulses. The free-running type of single-swing blocking oscillator produces pulses at a rate determined by the values of its grid capacitance and resistance. The repetition rate of a free-running single-swing blocking oscillator can be stabilized by an external synchronizing signal. A triggered single-swing blocking oscillator is pulsed into operation by external trigger pulses, and its repetition rate is determined by the repetition rate of the trigger signal applied.

ORAL QUIZ

1. Compare a free-running and a triggered single-swing blocking oscillator, with regard to factors governing the pulse recurrence frequency.
2. Explain the difference between synchro- Vary the repetition rate by changing the value of C1.
3. Explain under what conditions a single-swing blocking oscillator can be used as a triggered single-swing blocking oscillator.

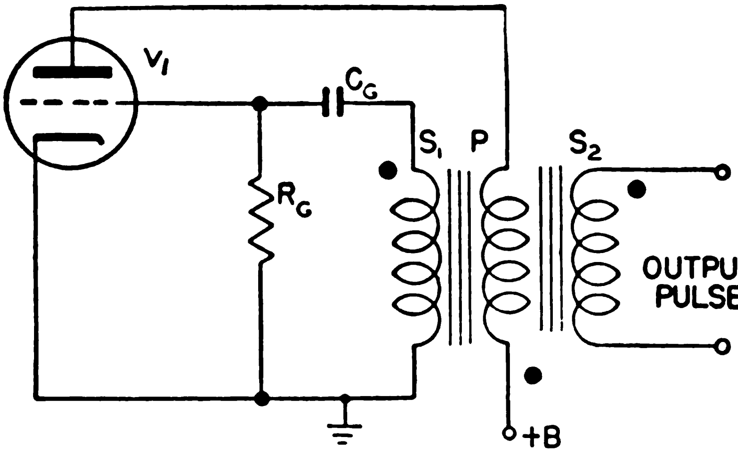


Figure 1

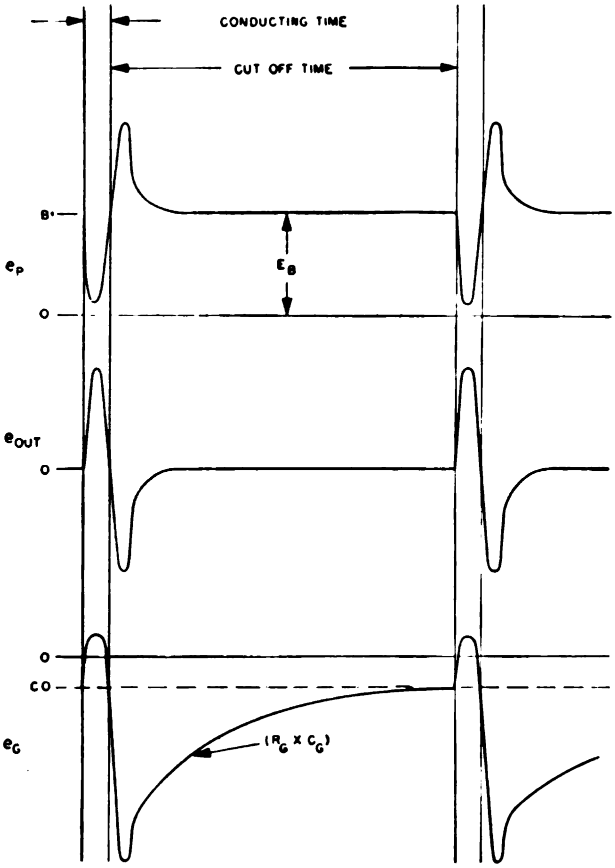


Figure 2

EXAMINATION No. 5

1. c . The self-pulsed blocking oscillator is:

a. Always controlled from an external trigger.

b. Actually a modified tuned-plate, tuned-grid oscillator.

c. A free-running Hartley type oscillator.

d. A modified Hartley oscillator which does not require a feedback path.

e. Actually a Hartley oscillator circuit with oversize grid-leak capacitor and resistor.

2. The self-pulsing blocking oscillator has two frequencies of operation. They are:

a. Carrier frequency.

b. Pulse repetition frequency.

3. What circuit components determine the frequency in a of problem 2, above?

The values L and C in the tank circuit.

4. What circuit components determine the frequency in b of problem 2, above?

The values of R and C in the grid circuit.

5. In connection with self-pulsed blocking oscillators, define:

Resting time: Time between output pulses.

Pulse width: Time during which oscillator is producing r-f energy.

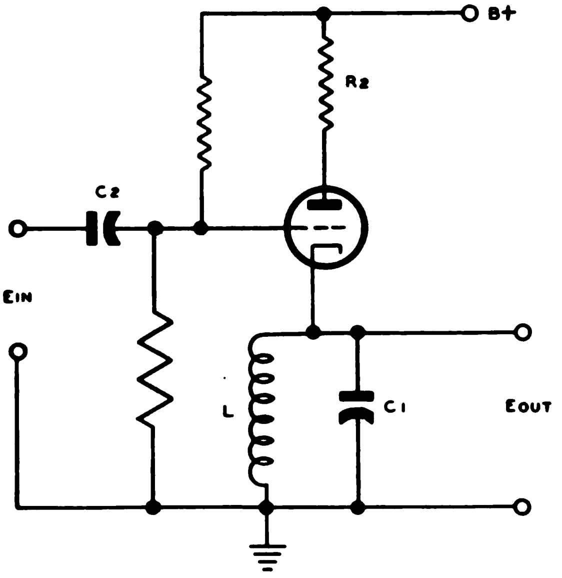


Figure 1

6. c . The duration of the r-f pulse in a self-pulsing oscillator is determined primarily by:

a. The values of L and C in the tank circuit.

b. The R-C combination in the grid circuit.

c. The grid capacitor.

d. The value of B+ on the oscillator.

7. d . Figure 1 is the circuit of:

a. A self-pulsed blocking oscillator.

b. A single-swing blocking oscillator.

c. A Hartley oscillator with positive grid return.

d. A shock-excited, or ringing, oscillator.

8. a . The circuit of figure 1:

a. Requires a negative square wave trigger input.

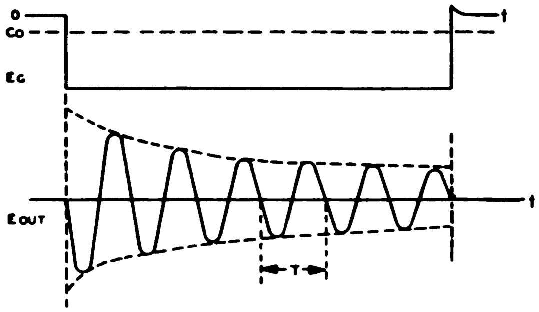
b. Requires a positive square wave trigger input.

c. Requires a positive peaked trigger input.

d. Requires a negative peaked trigger input.

e. Will operate quite satisfactorily without any trigger except a small sync pulse.

9. Draw the *output* waveform obtainable from the circuit of figure 1, indicating when it will begin and stop, in relation to the input voltage.



Suggested Drawing

10. d . In figure 2, resistor R2:

a. Serves to drop the B+ supply to the correct value of plate voltage needed for the tube.

b. Represents the resistance of the wire with which the coil, L, is wound.

c. Provides essentially critical damping, resulting in an oscillatory wave train at the output.

d. Produces essentially critical damping, resulting in a single pulse at the output.

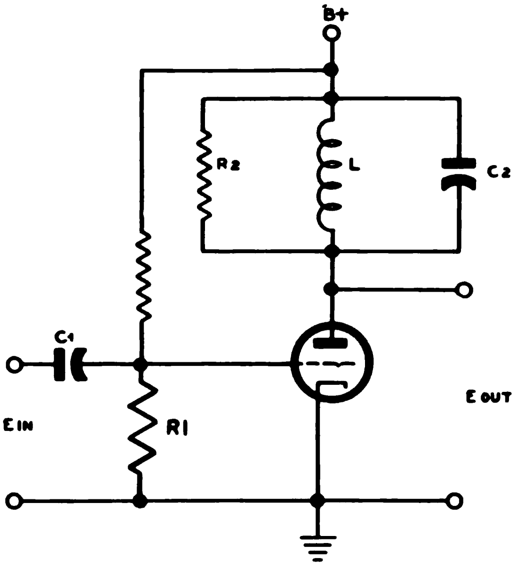


Figure 2

11. d. A resonant circuit which has the current through it interrupted by a gated tube is called a/an:

a. Interrupted tank circuit.

b. Self-pulsing oscillator.

c. One-shot multivibrator.

d. Ringing oscillator.

e. Single-swing blocking oscillator.

12. a. The circuit of figure 3 operates at a recurrence frequency determined by:

a. The R-C of the grid circuit.

b. The resonant frequency of the series combination of C and L2.

c. The parallel-resonant circuit consisting of C and L2. (It is a parallel circuit because R is very low and acts only as a damping resistor across the tank.)

d. The rate at which feedback occurs from plate to grid through L1 and L2.

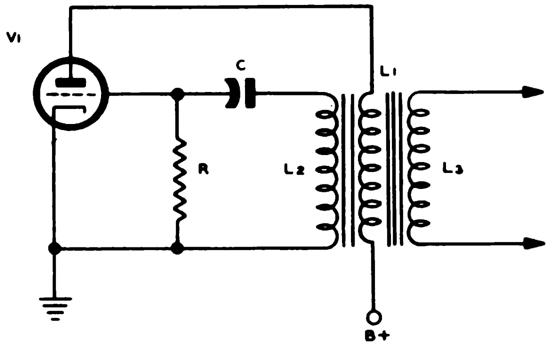


Figure 3

13. d. In figure 3, increasing R would:

a. Increase the frequency of oscillation.

b. Increase the discharge rate of C.

c. Increase the conducting time of the tube.

d. Increase the cut-off time of the tube.

e. Decrease the discharge time of C.

14. b. When synchronizing a single-swing blocking oscillator, it is usually desirable:

a. To have the free-running frequency higher than the forced frequency.

b. To have the free-running frequency lower than the forced frequency.

c. To have the free-running frequency the same as the forced frequency.

d. To have the forced frequency lower than the free-running frequency.

e. None of the above is correct. A blocking oscillator cannot be synchronized.

15. d. In figure 3, suppose that, in replacing a defective transformer, the leads of the grid winding were reversed. The effect would be:

a. It would make no difference, as far as circuit operation is concerned.

b. The circuit would oscillate, but at a higher frequency than normal.

c. The circuit would oscillate, but at a lower frequency than normal.

d. None of the above is correct; the circuit would not oscillate.

16. b. In a phantastron circuit, before the trigger is applied:

a. I_p is flowing; E_p is less than B+; E_k is positive; grid 1 is slightly positive; and I_{sg} is increasing.

b. I_p is cutoff; I_{sg} is maximum; E_k is positive; grid 1 is positive; and grid 3 is negative with respect to cathode.

c. E_p is at B+; grid 1 is also at B+; the capacitor between plate and grid 1 is charged; and E_k is positive.

d. A negative pulse of voltage exists at the cathode.

17. c. The purpose of a phantastron circuit is to:

a. Operate as a multivibrator.

b. Produce a positive spike of voltage at its plate at an accurately controlled rate.

c. Provide a controllable time delay in the form of a negative pulse with a variable trailing edge.

d. Provide a means of accurately counting an input pulse rate.

18. d . If the capacitance is increased in a series R-C circuit, the voltage drop across the capacitor will:

a. Be more in phase with the current through the capacitor.

b. Be more in phase with the applied voltage.

c. Increase.

d. Decrease.

19. a . A saw-tooth wave contains:

a. Even and odd order harmonics.

b. Only even order harmonics.

c. Only odd order harmonics.

d. Odd order harmonics out of phase.

20. c . The frequency of a free-running multivibrator is determined by:

a. The frequency of the trigger voltage.

b. The time between triggers.

c. The RC time constants of both tubes.

d. Only the value of applied B+.

21. c . Which of the following statements does *not* apply to a limiter?

a. It can be used to clip off the top of a waveform.

b. It can be used to pass a signal of only one polarity, and exclude others.

c. It can be used to determine and hold a reference-voltage level.

d. It can be used to produce square waves from sine waves.

22. List the two conditions of equilibrium in a multivibrator.

a. V1 conducting, V2 cut-off.

b. V2 conducting, V1 cut-off.

23. d . The main characteristic of a peaker circuit is that it produces a waveform that has a:

a. Sharp trailing edge and short duration.

b. Sloping leading edge and flat top.

c. Sloping leading edge and short duration.

d. Sharp leading edge and short duration.

24. b . In a multivibrator circuit:

a. A rise in the grid voltage of one tube causes a corresponding increase in the plate current of the other tube.

b. An increase of current through the load resistor of one tube causes the grid voltage of the other tube to decrease.

c. When current is flowing through V2, its associated plate coupling capacitor is charging.

d. The cathodes must stay positive with respect to the grids, in order to complete a full cycle of operation.

25. c . The function of a multivibrator is to produce:

a. Triggering pulses.

b. Exponential waveforms at the grid.

c. Square waves.

d. Pure sine waves.

26. c . An Eccles-Jordan multivibrator can be triggered by:

a. Positive pulses only.

b. Negative pulses only.

c. Negative or positive pulses.

d. None of the above is correct.

LESSON PLAN No. 21

SUBJECT

Counting circuits.

OBJECTIVE

To teach the theory and operation of counting circuits.

MATERIAL REQUIRED

1. Step Counting Demonstration Unit.
2. Single-Swing Blocking Oscillator Demonstration Unit.
3. Power Supply Demonstration Unit.
4. Five-inch cathode-ray oscilloscope.

INTRODUCTION

A counting circuit receives uniform pulses representing units to be counted, and produces a voltage proportional to the rate at which the pulses occur. By slight modifications, the counting circuit is used in conjunction with a blocking oscillator to produce a trigger pulse which is a submultiple of the frequency of the pulses applied.

SUBJECT MATERIAL

1. As an introduction to the subject of frequency counters, the concept of average (d.c.) value of a periodic wave should be reviewed.

2. Next, it should be shown that the average values of similar rectangular pulses can be utilized as measures of their relative frequencies. It must be emphasized, however, that in order for average values to be proportional to frequencies, the amplitudes and widths of the pulses must be the same.

3. The operation of the positive counter circuit should be explained, Figure 1.

a. Explain, step by step, the operation of the circuit upon the application of a positive square wave. Draw and discuss the waveforms appearing across R1.

b. Explain the operation of the circuit with the addition of a filter and a vacuum tube. Discuss the purpose of the filter, and the effect of changes in the frequency of the input pulses upon the magnitude of plate current, Figure 2.

4. The operation of the negative counter circuit should be explained. Begin with a negative square wave applied to the input, and explain the operation in a step-by-step manner, Figure 3.

a. Draw and discuss the voltage waveform appearing across R1.

b. Discuss the effect which changes of input frequency will have on plate current when the negative counter is connected to the filter and vacuum tube.

5. As a preliminary to discussion of the step counting circuit, the following points should be reviewed.

a. Formula for the charge on a capacitor: $Q = CE$, and for the voltage on a capacitor: $E = Q/C$.

b. Formula for the total capacitance of two capacitors in seres: $C_T = \dfrac{C1C2}{C1 + C2}$.

c. The charge on two capacitors in series is equal to $Q_1 + Q_2$ which is equal to the total charge: $Q_T = C_T E$.

d. The formula for voltage across each of the series capacitors, as developed from a, b, and c above:

$$\frac{E_1}{E_2} = \frac{Q_1 C2}{Q_2 C1}.$$

6. Explain the operation of a step counting circuit. Explain the charge of C1 and C2 in series through the second tube, and the discharge of C1 through the first tube, Figure 4.

Draw the output waveform of the step voltage developed across C2, and discuss the relative sizes of the voltage steps, Figure 6.

7. Discuss the operation of a frequency-division circuit consisting of a blocking oscillator triggered by a counter circuit, Figure 5.

Explain the effect of varying the bias of the blocking oscillator in determining when it will trigger and thus establish the frequency of the input pulses to the counter and the output pulses of the blocking oscillator.

8. Set up the Single-Swing Blocking Oscillator, Step Counter, and Power-Supply Demonstration Units, and the oscilloscope. Show the relative frequency of the input and output waveforms. Vary R2 and discuss its effects on the output frequency as the input frequency remains constant.

CONCLUSIONS

Frequency counters measure frequency by measuring the average value of a recurring pulse waveform. In order to measure relative frequencies of pulsed rectangular waves, their amplitudes and widths must be equal.

Frequency dividers operate by charging a capacitor, in a number of input cycles, to a value sufficient to trigger a blocking oscillator. Thus, the blocking oscillator produces one output pulse for n input cycles, and so operates at 1/n of the input frequency.

ORAL QUIZ

1. In Figure 6 the triggering voltage is set at 30 volts. If the voltage rises to 15 volts after exactly six cycles of input voltage, will the tube fire after exactly 6 cycles? Before 6 cycles? After more than 6 cycles?
2. In Figure 5, what is the effect of varying the bias?

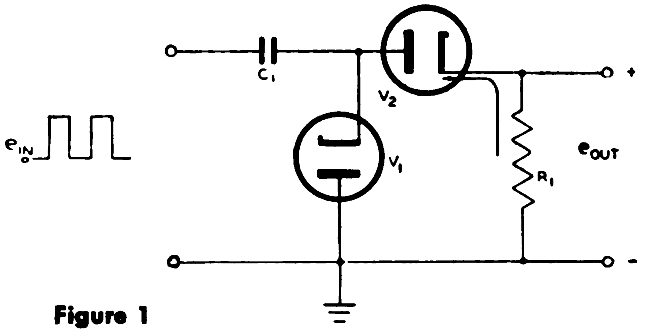


Figure 1

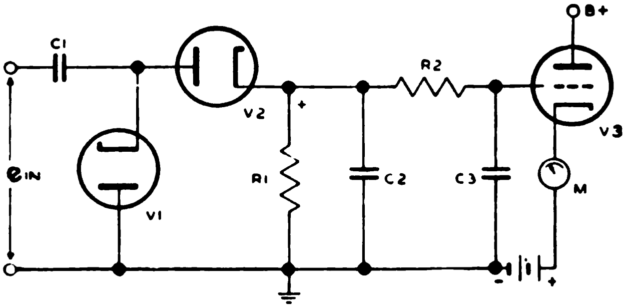


Figure 2

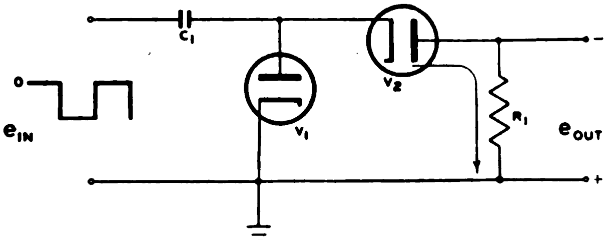


Figure 3

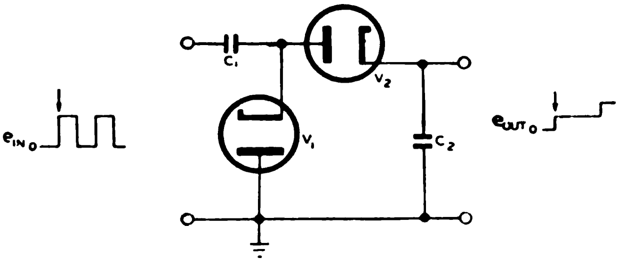


Figure 4

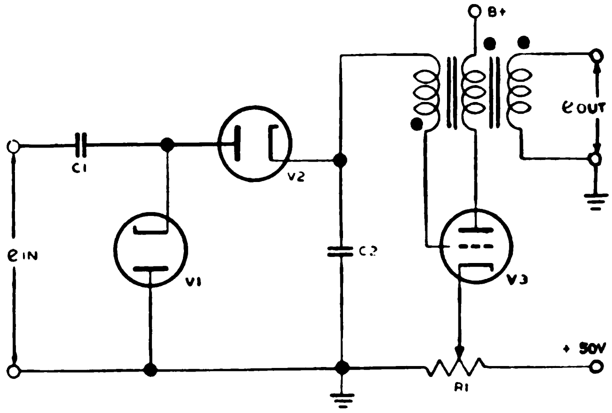


Figure 5

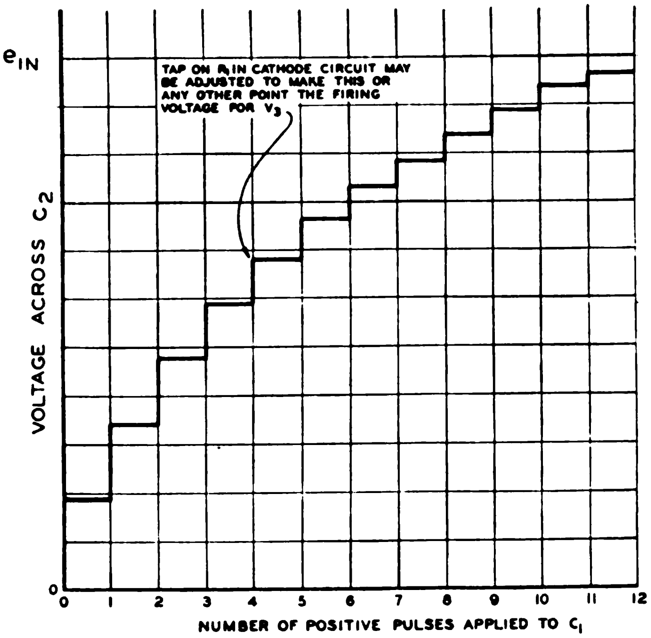


Figure 6

LESSON PLAN No. 22

SUBJECT

Characteristics of neon tubes and thyratrons; introduction to saw-tooth generators; the neon saw-tooth generator.

OBJECTIVE

To explain the theory of neon and thyratron tubes, and their applications in developing saw-tooth waveforms.

INTRODUCTION

Voltages having saw-tooth waveforms are extensively used in radar and oscilloscopes. Saw-tooth generators in the simplest form make use of the neon tubes. In radar, thyratrons are used as saw-tooth generators. These tubes are also used in motor-control circuits. The thyratron, rather than the neon bulb, is in general use as a saw-tooth generator, because its characteristics are better suited to the purpose.

SUBJECT MATERIAL

1. Describe the characteristics of the neon tube:

a. The neon, or glow lamp, is a two-element gas-filled tube. If the two elements are alike in size and shape, the tube will conduct in either direction depending upon the polarity of the applied potential. The direction of current flow will always be toward the element having the higher potential.

b. Conduction through the neon tube occurs when the gas is ionized. Ionization takes place at a certain voltage value for a particular tube. The voltage value at which ionization occurs is called the firing or striking, potential. Following ionization, the tube will conduct until the voltage falls to a value which will no longer maintain ionization. This low-voltage value is called the deionization, or extinction, potential. Upon ionization, comparatively large currents, at low voltages, are conducted through the tube.

c. Because the neon tube offers almost infinite resistance in a circuit when the voltage is too low to start conduction, and offers a very low resistance after sufficient voltage has been applied to start conduction, the tube is, in effect, an electronic switch.

d. Show the schematic symbol for this type of tube.

2. Describe the characteristics of the thyratron:

a. The thyratron is a gas-filled tube (triode or tetrode) having a control grid. The grid voltage is used to control the firing potential (the point at which the gas ionizes and conduction through the tube begins). Thyratrons generally employ a hot cathode.

b. The greater the negative voltage on the grid, the higher the voltage required across the tube to produce the required starting current for ionization.

c. Once the thyratron fires (and conduction takes place through the tube), the grid loses control, and cannot affect the current flow.

d. Voltage across the thyratron must be removed, or reduced to nearly zero value, before the control grid will again take control and prevent conduction.

e. Show the schematic symbol for this type of tube.

3. Draw the grid control characteristics curve of typical thyratrons, Figure 1.

a. Explain the "critical bias" curve, to the class.

b. Use the curve to illustrate clearly the relationship of grid bias to d-c plate voltage.

c. Point out that higher negative grid bias requires higher d-c voltage across the thyratron for ionization of gas and conduction through the tube.

4. Describe the differences in the characteristics of the neon bulb and the thyratron.

a. Voltage drop across a thyratron is less.

b. The thyratron will pass a larger instantaneous current.

c. The thyratron deionizes in a shorter time.

d. The thyratron ionizes more dependably; this enhances the frequency stability of the thyratron circuit over that of the neon-bulb circuit.

e. When used as a sweep generator, higher frequencies of operation are possible with the thyratron circuit than with the neon-tube circuit. This is due to the larger instantaneous current capacity and shorter deionization time of the thyratron.

5. Draw the neon saw-tooth generator circuit, and present to the class a step-by-step explanation of the circuit operation, Figure 2.

a. State the necessity for application of a sufficient voltage to fire the neon bulb and start conduction.

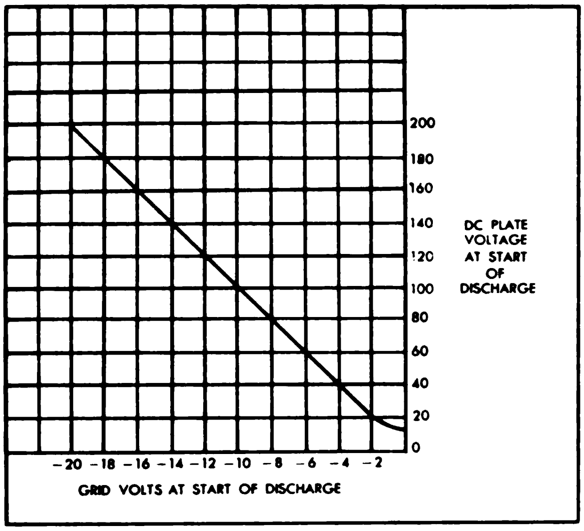


Figure 1

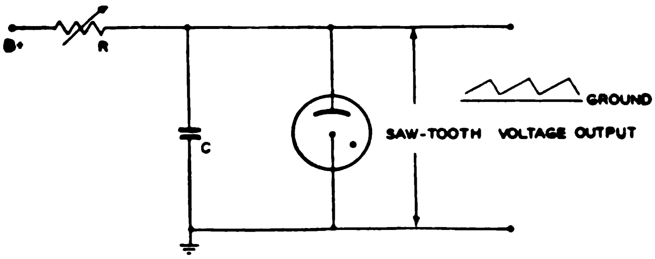


Figure 2

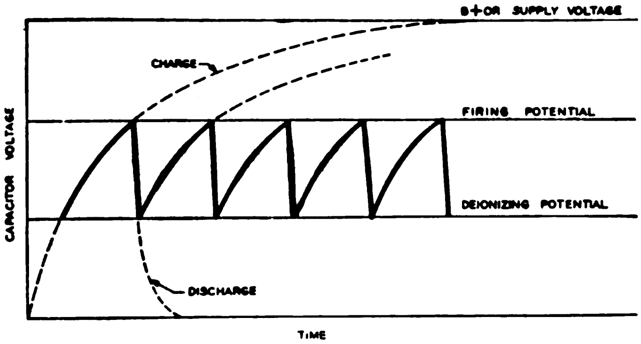


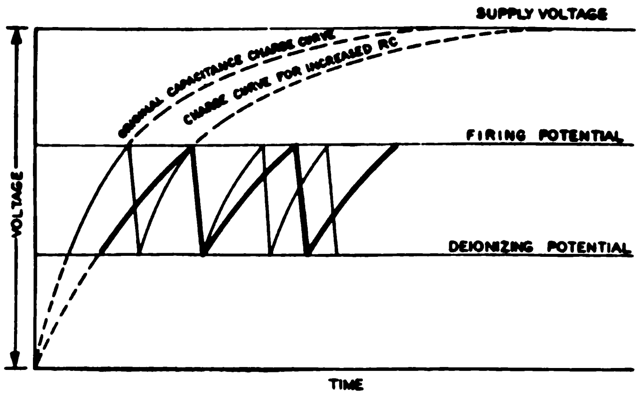
Figure 3

b. Explain how this firing, or ionization, potential is built up in the capacitor.

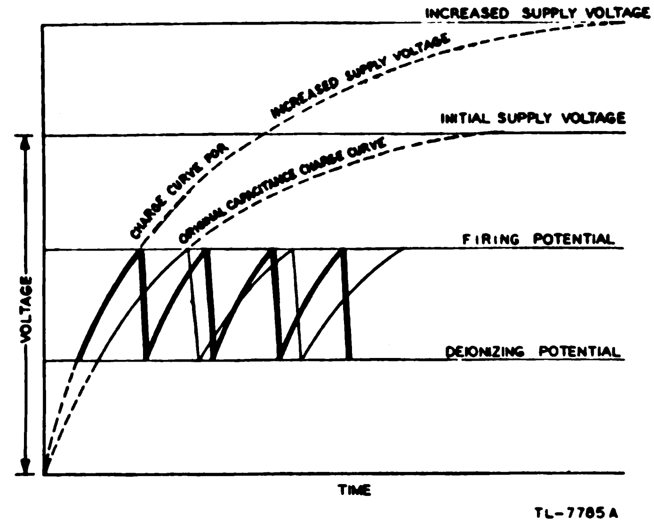
c. Explain why and how the capacitor discharges upon reaching the firing potential.

d. Explain why the capacitor charging time is readily controlled.

6. Draw the variation of capacitor voltage in the neon saw-tooth generator; present to the class a step-by-step explanation of the generation of the saw-tooth output waveform, Figure 3.


SUPPLY VOLTAGE
ORIGINAL CAPACITANCE CHARGE CURVE
CHARGE CURVE FOR INCREASED RC
FIRING POTENTIAL
DEIONIZING POTENTIAL
VOLTAGE
TIME

① CAPACITANCE OR RESISTANCE INCREASED, FREQUENCY DECREASED.



② SUPPLY VOLTAGE INCREASED, FREQUENCY INCREASED.

Figure 4

a. Stress that wave formation is the result of capacitor charge and discharge.

b. Point out the location of the most linear portion of the waveform.

7. Draw curves and explain to the class the effect on frequency of an increase of capacitance or resistance, Figure 4.

Show how an increase in capacitor charging time decreases the output frequency.

8. Draw curve and explain to the class the effect on frequency of an increase in d-c supply voltage, Figure 4.

a. Show how a decrease in capacitor charging time, due to higher charging voltage, is responsible for an increase of output frequency.

b. Call the attention of the class to the increase of the linear portion of the wave-front slope as a result of employing higher charging potential.

9. Define and discuss the term "linear" as applied to sweep voltage and waveforms.

10. Discuss the application of a linear sweep voltage to the oscilloscope. Show the necessity for a linear sweep-voltage waveform to produce patterns of signal voltage with a minimum of distortion.

a. Draw the sketches shown below on the blackboard, and give the class a review of the effects of linear and non-linear sweeps on a signal pattern.

b. Explain to the class that when a linear sweep voltage is applied to the horizontal deflection plates of the oscilloscope, the spot will move across the screen from left to right, to form a time base.

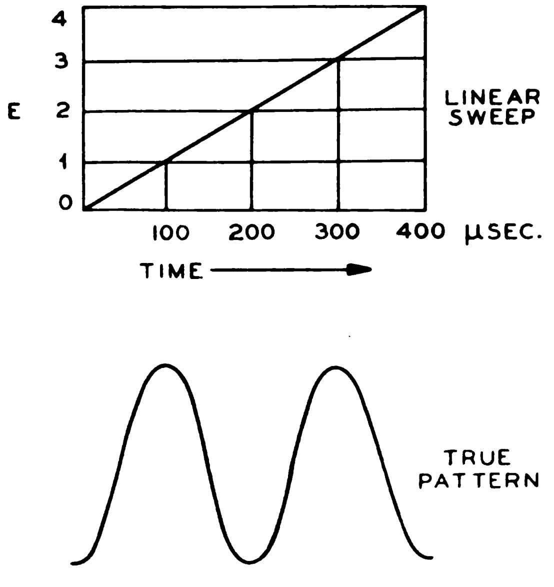
c. Explain to the class that a linear sweep voltage will result in a linear time base. Also, show that, similarly, non-linear sweeps result in non-linear time bases.

d. Show that the linear movement of the spot establishes a base for measuring time.

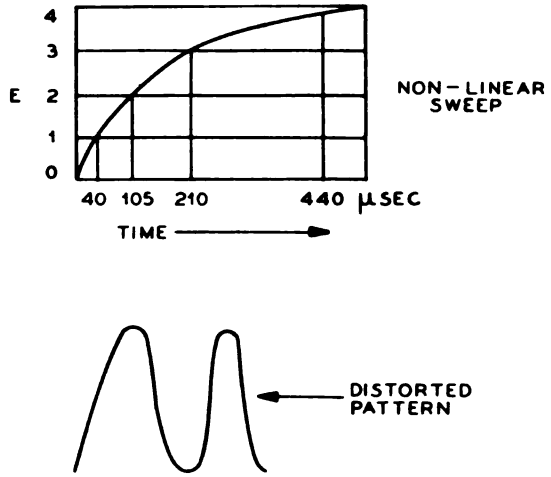
CONCLUSIONS

It is evident that the thyratron is generally superior to the neon tube for use as a saw-tooth waveform generator.

It is also evident that the saw-tooth waveform should present the best linearity possible when used for the sweep voltage for cathode-ray oscillograph tubes.



Linear Sweep



Non-linear Sweep

The linearity of the frontal slope of the saw-tooth waveform is dependent upon the brevity of the capacitor charging rate.

ORAL QUIZ

1. What controls conduction through a neon bulb?

2. Explain how a neon bulb acts as an electric switch.

3. When does the neon bulb offer:
    a. Extremely high impedance?
    b. Very low impedance?

4. In what respects does the thyratron differ from the neon bulb?

5. What is the "critical bias" of a thyratron tube?

6. Why does the capacitor in a neon-tube saw-tooth generator discharge periodically?

7. Which is greater, the capacitor charging rate or its discharging rate? Why?

8. How is the output frequency of the neon saw-tooth waveform generator readily changed?

9. Name three reasons why a thyratron would be preferable to a neon bulb as a saw-tooth waveform generator.

10. What determines the linearity of the front of a saw-tooth waveform generator by a neon-bulb generator?

11. Can you obtain an undistorted pattern of a signal-voltage waveform on the oscilloscope screen when employing a non-linear sweep voltage?

12. Would you identify the neon tube saw-tooth waveform generator as a relaxation oscillator? Why?

LESSON PLAN No. 23

SUBJECT

Thyratron saw-tooth generators; synchronization.

OBJECTIVE

To explain the theory of the saw-tooth generator, and synchronization of the generator with a constant frequency.

MATERIAL REQUIRED

1. Thyratron Saw-Tooth Generator Demonstration Unit.
2. Five-inch cathode-ray oscilloscope.
3. Vacuum-tube voltmeter.
4. Audio signal generator.
5. Bias Supply Laboratory Chassis.

INTRODUCTION

Thyratron saw-tooth generators are widely used in radar systems and in oscilloscopes. They are most commonly used as sweep generators for cathode-ray tubes. This generator is a form of relaxation oscillator, and is similar in operation to the neon saw-tooth generator, but is different in that it is much more stable.

SUBJECT MATERIAL

1. Draw the simple thyratron saw-tooth generator circuit and the curve showing the changes in amplitude and frequency of the output with changes in grid bias. Explain the circuit operation to the class, Figure 1 and Figure 2.

a. Show that the thyratron gas triode is used as an electronic switch to periodically discharge the capacitor in the R-C circuit.

b. Point out that the thyratron acts in the same manner as the neon tube, except that the firing, or ionization, potential is controlled by the thyratron control grid, which is always biased negatively.

c. Using the curves illustrating changes of amplitude and frequency in the output of the thyratron circuit, explain that the value of the negative grid potential determines the amplitude of the output saw-tooth waveform. Show that the more negative the grid becomes, relative to the cathode, the higher will be the firing potential of the tube, Figure 2.

d. Note that the value of grid bias has very little effect on the deionization, or extinction, potential.

e. Explain that the output frequency may be varied in the same manner as in the neon saw-tooth generator, i.e., an increase in the capacitance or resistance in the R-C circuit causes a decrease in frequency and, similarly, a decrease in supply voltage causes a decrease in frequency.

2. Draw thyratron relaxation oscillator and output waveforms. Using this diagram, present to the class a summary of the generator action and the functioning of the frequency controls.

a. Show that the electronic switch "closes" (tube fires) at a voltage that can be controlled by the grid bias.

b. Show that the lower 10% of the curve is essentially linear; show, also, that the linearity drops off rapidly as the curve rises beyond this point, and that the use of a high plate-supply voltage and a low firing potential improves the linearity of the saw-tooth waveform.

3. Discuss the synchronization of the thyratron saw-tooth generator.

a. State that the oscillations of a gas tube relaxation oscillator are not stable in frequency.

b. Explain that frequency stabilization can be obtained by synchronization with a signal of constant frequency, equal to approximately the natural operating frequency of the thyratron generator, or with multiple or submultiples of that frequency.

c. Draw the circuit of the synchronized thyratron saw-tooth generator on the blackboard. Illustrate to the class that this saw-tooth oscillator can be synchronized by injecting a small voltage of constant frequency to the grid, Figure 3.

d. Show the synchronization of the thyratron saw-tooth generator with sine waves. Using the diagram, present a step-by-step analysis of the synchronizing action, Figure 4.

(1) Explain why the natural frequency of the saw-tooth generator is adjusted to a value slightly lower than the synchronizing frequency.

(2) Carefully explain the variation in firing potential brought about by the synchronizing voltage.

(3) Illustrate how the firing point varies in accordance with the synchronizing voltage on the grid.

(4) Show how reduction in the time for

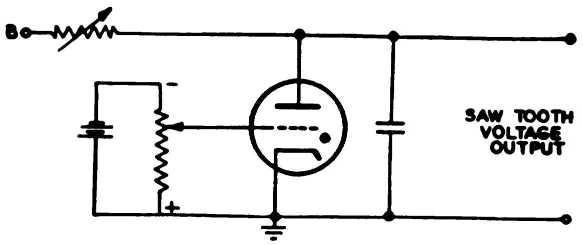


Figure 1

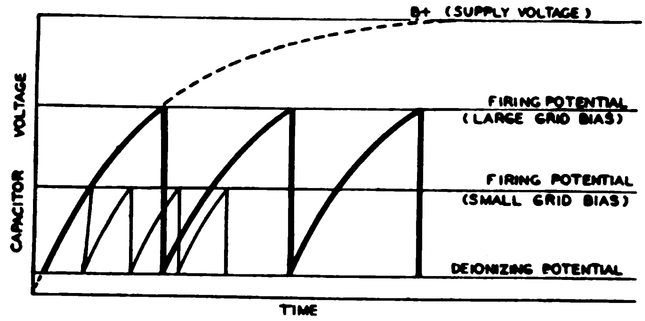


Figure 2

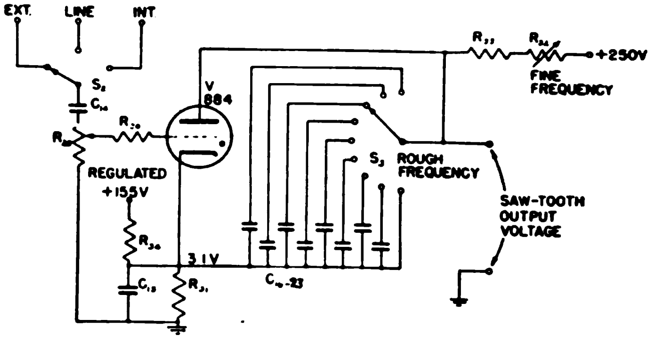


Figure 5

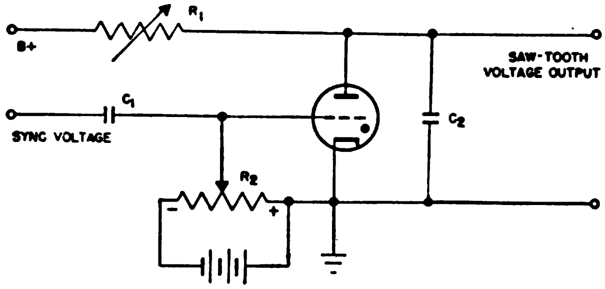


Figure 3

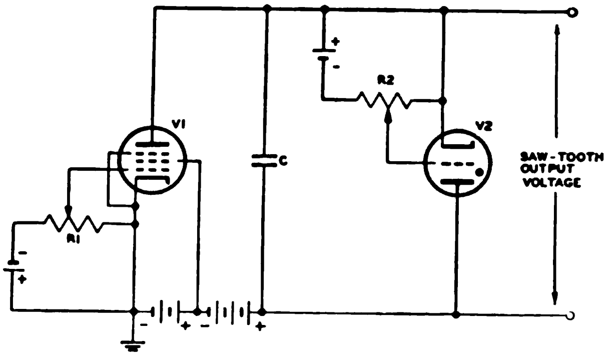


Figure 6

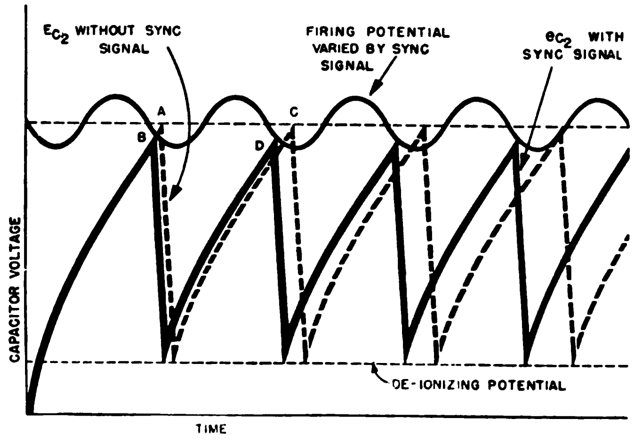


Figure 4

each oscillation results in the "locking" of the oscillator to the frequency of the signal voltage injected on the grid.

(5) Explain how the thyratron generator may be "locked" to a multiple or submultiple of the synchronizing frequency in a similar manner.

4. Conduct a class demonstration of the SUBJECT MATERIAL discussed in paragraphs 1, 2, and 3 using the Thyratron Saw-tooth Generator Demonstration Unit, vacuum tube voltmeter, Power Supply Demonstration Unit, a-f signal generator, cathode-ray oscilloscope, and the Bias Supply Chassis.

a. Connect the a-f signal generator, and adjust it to a frequency near (but lower than) the natural operating frequency of the saw-tooth generator.

b. Using this equipment, illustrate the synchronization of the saw-tooth generator near its natural frequency, and near a submultiple of the natural frequency.

c. Show the output waveform changes from a non-synchronized to a synchronized output.

d. Note that the value of synchronizing voltage required is relatively low.

e. Show the effects of open resistors and capacitors, defective tube, low plate-supply voltage, failure of bias voltage, and variation of synchronizing-voltage frequency.

f. Demonstrate "coarse" and "fine" frequency control of the saw-tooth output by substituting different values of C1 and R2; choose a frequency setting of the a-f signal generator, and synchronize the saw-tooth generator with this frequency.

5. Draw the thyratron saw-tooth sweep generator circuit and show the class how this circuit is employed as a sweep generator for an oscilloscope, Figure 5.

a. Explain the method used to bias the thyratron grid with a fixed negative voltage. Call attention to the use of a regulated source of voltage supply, to improve stability.

b. Point out the capacitor bank with the selector switch for "coarse" frequency control; also, point out the variable resistor for "fine" frequency control. Mention that the frequency range for this particular oscilloscope (Dumont 208) is from 2 c.p.s. to 50 kc.

c. Apply the output of the Thyratron Saw-Tooth Generator Demonstration Unit to the horizontal input of the oscilloscope.

(1) Turn off the internal sweep generator of the oscilloscope.

(2) Adjust the saw-tooth generator to produce a linear sweep. Note that a smaller amplitude is produced when it is adjusted for good linearity.

(3) Apply a sine wave from the a-f oscillator to the vertical input of the oscilloscope, and show the evenly spaced sine waves, indicating good linear sweep.

(4) Adjust the saw-tooth generator for a non-linear output, noting the larger amplitude of the sweep voltage, and the non-linear arrangement of the sine wave appearing on the screen.

(5) From the a-f oscillator, apply a synchronizing voltage to the saw-tooth generator.

(6) Show the stabilizing effects of synchronization, and the effects of excessive synchronizing voltage (disappearance of sine-wave cycles from the right-hand side of the wave pattern).

6. Draw the controlled charging current thyratron circuit, and explain to the class the method whereby it may be modified to produce a linear sweep-output voltage, Figure 6.

a. Give the reason for replacing the charging resistor with the pentode tube, operated as a constant-current device.

b. Explain to the class how the use of the constant-current pentode will result in the production of a linear waveform in the generator output circuit.

CONCLUSIONS

The thyratron saw-tooth generator affords a simple and flexible means for producing linear saw-tooth waveform voltage. It is widely used as a sweep generator for cathode-ray tubes.

ORAL QUIZ

1. For what purpose is the thyratron generator used?

2. Draw a schematic diagram and explain the operation of the thyratron saw-tooth generator.

3. Explain how to synchronize the thyratron generator with a constant-frequency signal.

4. Set up the demonstration unit, employing the apparatus used during the lesson. Select a constant-frequency signal and synchronize the thyratron generator with the signal.

5. Demonstrate a method of trouble shooting the circuits on the demonstration unit when the thyratron is synchronized with the constant-frequency signal.

6. Insert troubles into the circuit, and have students volunteer to remove them.

LESSON PLAN No. 24

SUBJECT

Vacuum-tube saw-tooth generators; trapezoidal waveform generators.

OBJECTIVE

To teach the theory of the vacuum-tube saw-tooth and the trapezoidal waveform generators.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Demonstration Unit.
2. Cathode Follower Demonstration Unit.
3. One-Shot Multivibrator Demonstration Unit.
4. Vacuum-Tube Saw-Tooth Generator Demonstration Unit.
5. Power Supply Demonstration Unit.
6. Vacuum-tube voltmeter.
7. Five-inch cathode-ray oscilloscope.

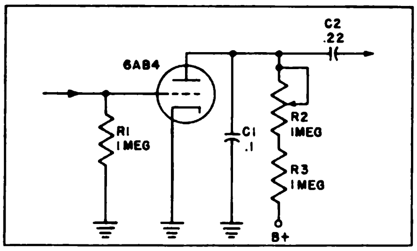


Figure 1

INTRODUCTION

The vacuum-tube saw-tooth generator is used where the time duration of an output sweep signal is to be rigidly controlled by the width of a gate pulse applied to the generator input.

The trapezoidal waveform generator fulfills the need for the trapezoidal voltages required to produce saw-tooth waveform voltages in a magnetic deflection coil.

SUBJECT MATERIAL

The Saw-tooth Generator

1. Draw on the blackboard the schematic of a vacuum-tube saw-tooth generator, and present to the class a step-by-step explanation of circuit operation, with the aid of waveforms, Figure 1.

a. Make clear that the vacuum-tube saw-tooth generator is not a relaxation oscillator; the tube conduction is entirely under the control of the grid.

b. Explain the steady-state condition of the circuit before application of a gate pulse.

c. Continue with a description of circuit action after pulse application. Draw curves on the board to illustrate the shape of the applied pulse and the development of the final saw-tooth waveform in the output circuit.

d. Explain why variations in R or C values do not affect the output frequency.

e. Discuss variations in both R and C values, and supply-voltage value, and show their effects upon both the linearity and amplitude of the output waveform.

f. Discuss variations in both frequency and width of the applied gate pulse, to show the effects of these variations on the output waveform, in ragard to linearity, amplitude, and frequency.

g. Show that the saw-tooth waveform can also be produced from a vacuum-tube generator which is normally in a conducting condition.

2. Demonstrate the operation of a vacuum-tube saw-tooth generator.

a. Set up the Single-Swing Blocking Oscillator, Cathode Follower, One-Shot Multivibrator, Vacuum-Tube Saw-tooth Generator, and Power Supply Demonstration Unit. Adjust the load resistor of the cathode follower to produce a trigger pulse of proper amplitude to drive the one-shot multivibrator properly.

b. Using the oscilloscope, show the waveform of the gating pulse applied to the input of the saw-tooth generator.

c. Show the output waveform.

d. Vary the width of the gate pulse, and observe the changes in waveform of the output saw-tooth.

e. Using a narrow gating pulse, vary the charging resistance value in the saw-tooth generator, and note its effect upon linearity.

The Trapezoidal Generator

1. Draw the equivalent circuit of a coil containing resistance, and show, with voltage waveforms, how a saw-tooth current is produced in an inductance.

Describe the application of the trapezoidal waveform to the deflection coil of an oscilloscope.

2. Draw the circuit of the trapezoidal generator, including a current amplifier, Figure 2.

a. Using the circuit, explain to the class the steady-state condition of the trapezoidal generator.

b. Call attention to the necessity for operating V1 so that C1 charges on the linear portion of the charging curve. Mention that a pentode, operated as a constant-current device, could be used to secure a linear charging voltage for C1.

3. Draw the voltage waveforms for the circuit in paragraph 2. Using these curves, give the class a step-by-step explanation of circuit operation upon application of the trigger or gate pulse.

a. Direct attention to the wave shape of the output voltage appearing at the plate.

b. Stress the effect of the resistor in series with the charging capacitor, showing why it causes the steep initial rise.

4. Demonstrate the action of the trapezoidal generator:

a. Insert a stepping resistor in the Vacuum-Tube Saw-tooth Generator Demonstration Unit, and illustrate the step it produces on the saw-tooth.

b. Insert several other values and note the waveform changes that occur.

c. Call upon the class to explain the observed changes.

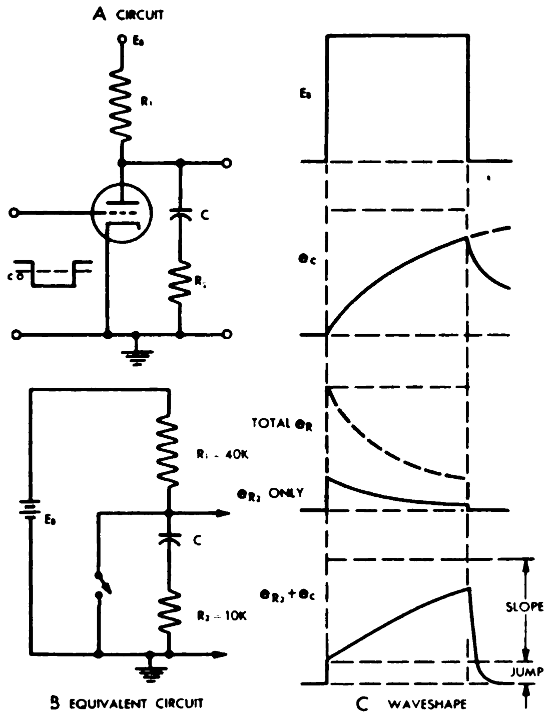


Figure 3

CONCLUSIONS

The vacuum-tube saw-tooth generator is of value when the time duration of the sweep signal must be rigidly controlled by the width of a gate pulse.

The trapezoidal waveform generator provides the voltage waveform required to produce saw-tooth currents in a coil which includes resistance.

ORAL QUIZ

1. In the vacuum-tube saw-tooth generator, what determines:

a. Saw-tooth output frequency?

b. Linearity of output waveform?

c. Time duration of output sweep signal?

2. Name the shape and source of the waveform used as a triggering gate voltage.

3. Considering the trapezoidal (Figure 3) generator:

a. How must the tube be operated to obtain proper capacitor charging?

b. Why must a trapezoidal generator be used, instead of a saw-tooth generator, to produce a saw-tooth sweep voltage in a deflecting coil of a cathode-ray tube?

c. What device could be used in this generator to secure a linear charging current for the RC circuit capacitor?

d. To what does the charging capacitor in this generator owe the steep initial charging rise?

e. In this generator, the sum of what voltages produces the output trapezoidal waveforms?

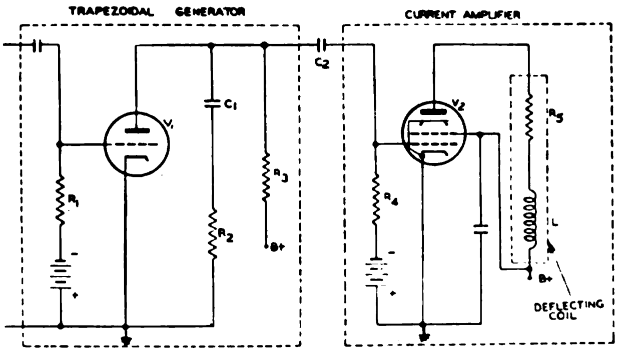


Figure 2

LESSON PLAN No. 25

SUBJECT

Bootstrap sweep generator circuit and expanded sweep generators.

OBJECTIVE

To teach the theory and application of the bootstrap sweep generator circuit and expanded-sweep generators.

INTRODUCTION

The bootstrap circuit provides a very good means of improving the linearity of the sawtooth sweep on an oscilloscope.

The expanded-sweep circuit is used to expand the horizontal sweep by speeding the sweep of the electron beam across the screen for a part of the time.

SUBJECT MATERIAL

1. Draw the circuit of the bootstrap sweep generator on the board, and explain the name bootstrap, Figure 1.

2. Describe the static conditions of operation.

a. V1 conducting heavily.

b. C essentially discharged.

c. V2, a cathode follower, conducting at a constant rate.

d. V3, a cathode follower, conducting.

3. Describe the action when a negative square wave is applied to the grid of V1.

a. V1 is cut off.

b. E_{p1} rises, causing E_{G2} to do likewise.

c. E_{k2} follows the grid of V2, due to its action as a cathode follower.

d. E_{k3} rises with E_{k2} through C_c.

e. The voltage drop across R_L then remains the same as when V1 was conducting.

f. Current flow through R_L is now the charging current of C. Since E_{R_L} is made to remain essentially constant, due to the feedback action of V2, the charging current of C remains constant. This causes the voltage across C to rise linearly.

g. The linear rise of E_C results in a linear rise of E_{K2}.

h. V3 functions to allow the voltage coupled to R_L through C to rise above the supply potential during the rise time of C.

i. C charging current flows through R_L into C_c to maintain the charge on this capacitor constant as E_{K2} rises.

j. V3 is cut off during the time the gate pulse is applied to V1.

4. Draw the circuit diagram of the expanded-sweep generator and explain the operation of the circuit, Figure 2.

a. Explain the need for, and the advantage gained with, such a circuit.

b. Show the waveforms of the sweep-expansion circuit.

5. Explain the operation of the circuit given in Figure 3, using waveforms to aid the discussion.

CONCLUSIONS

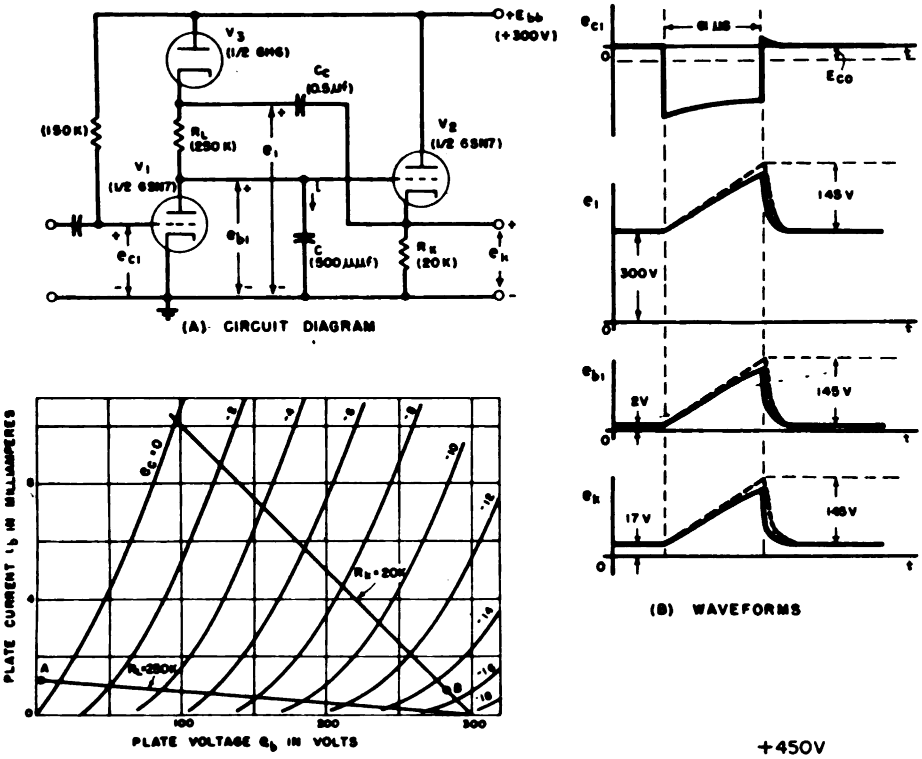
When the sweep of the electron beam across the screen is speeded for a part of the time and the notch is expanded, the pips are much easier to read, and the reading becomes more accurate.

ORAL QUIZ

1. What is meant by the "expanded sweep"?

2. What triggers the sweep-expansion generator?

3. Why is the sweep-expansion-generator tube normally cut off?



(A) CIRCUIT DIAGRAM

(B) WAVEFORMS

(C) PLATE CHARACTERISTICS OF 6SN7

Figure 1

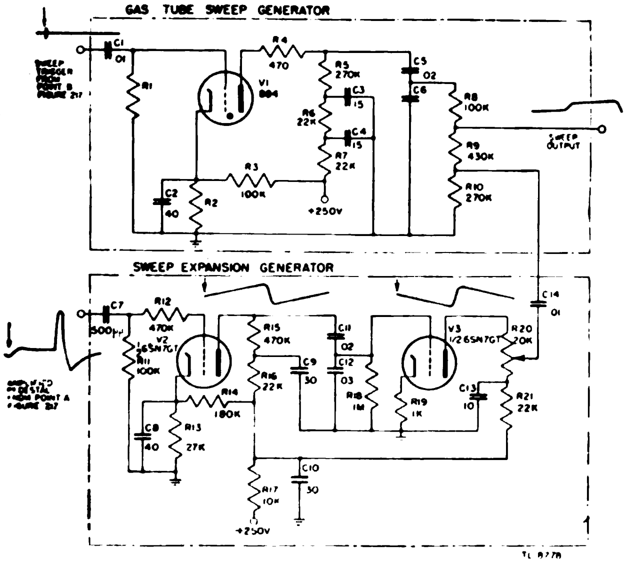


Figure 2

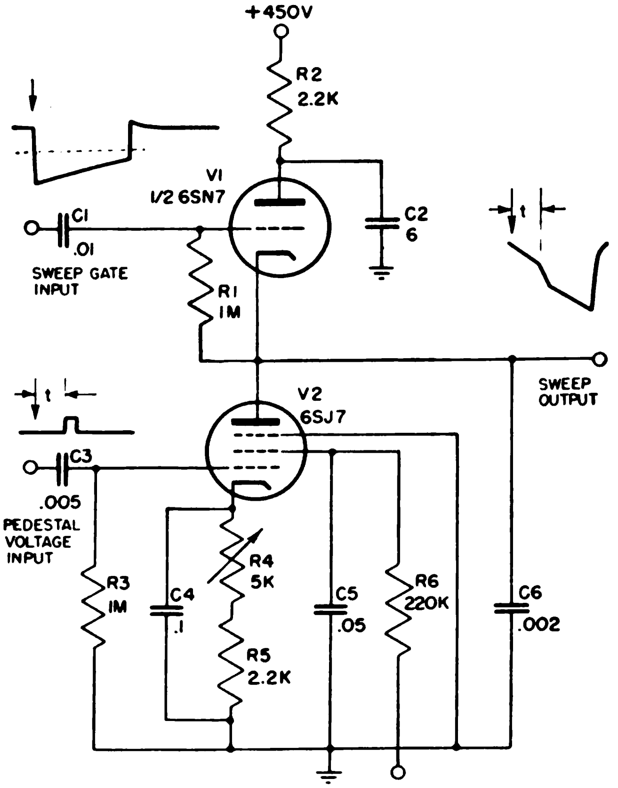


Figure 3

EXAMINATION No. 6

NOTE: A cover page, similar to the one shown on page 8, should be reproduced with this examination for student use.

1. List three factors that control the frequency of operation of a simple neon tube saw-tooth generator.

a. The supply voltage.

b. RC time constant of the charging-capacitor circuit.

c. Ionization and deionization potentials of the neon tube.

2. Give three reasons why a thyratron is preferable to a neon tube for use in a saw-tooth generator circuit.

a. May be synchronized.

b. More uniform as to firing and deionization potentials.

c. Deionizes more quickly.

d. Will operate at higher frequency.

e. Greater peak tube current.

f. Lower IR drop across tube.

3. _a_. A vacuum-tube saw-tooth generator:

a. Must be triggered to obtain proper operation.

b. Produces a better saw-tooth than a gas tube saw-tooth generator, because lower potentials can be used.

c. Produces a more linear saw-tooth than a gas tube saw-tooth generator, irrespective of applied potentials.

d. Is a free-running saw-tooth generator.

e. Operates in such a manner that the charging capacitor discharges during the cutoff time of the tube.

4. _c_. The result of synchronizing a sweep generator is:

a. To improve the linearity of the saw-tooth voltage rise.

b. To reduce the flyback time to nearly zero.

c. To make the sweep frequency some multiple or submultiple of the signal input frequency.

d. To make the sweep time just long enough to allow one complete cycle to appear on the scope.

5. _b_. The linearity of a thyratron saw-tooth generator may be improved by substituting a pentode tube for the charging resistor. Linearity is improved because:

a. The trigger input voltage to the saw-tooth generator allows a more precise control of charging current than is the case where the thyratron is triggered.

b. Plate-voltage changes do not result in plate-current changes.

c. Plate voltages will change very linearly as plate current changes.

d. The plate-voltage change is exactly 180° out of phase with grid-voltage change.

6. _d_. Why is the initial vertical rise of a trapezoidal waveform necessary when dealing with electro-magnetic deflection?

a. To compensate for the effect of the resistance of the coil.

b. To compensate for the distributed capacitance of the coil.

c. To decrease the initial inductance of the coil, which will allow a linear current rise.

d. None of the above is correct.

7. _c_. A principal characteristic of a thyratron is:

a. It has a blue glow ionized.

b. It has a higher firing potential, because of the existence of a grid in the tube.

c. It cannot be controlled by grid bias after firing.

d. It requires a bias voltage on the grid in order to operate.

8. _d_. In figure 1, a trapezoidal voltage output is obtained across:

a. R2+V1.

b. C1+R2.

c. R2+R3.

d. C1+R3.

e. R2+R3+C1.

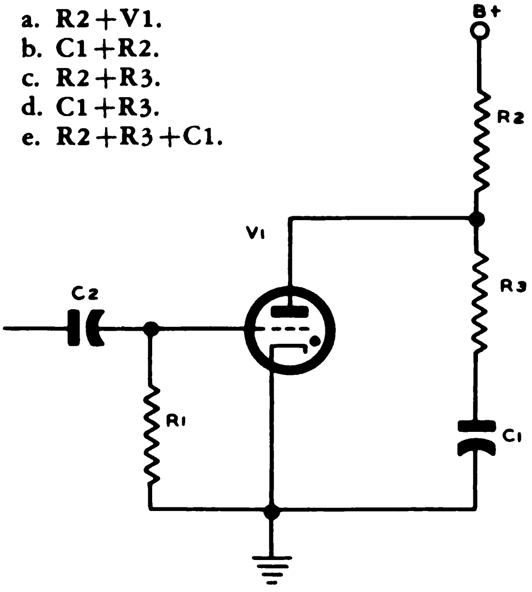


Figure 1

9. d. In a vacuum-tube saw-tooth generator, the saw-tooth output frequency:

a. Is not externally controlled.

b. Has a rise time linearity determined, in part, by the value of plate-supply voltage applied to the circuit.

c. Has a time per cycle equal to the time the tube is cut off.

d. Has a time per cycle equal to the rise time plus the flyback time.

10. b. Referring to figure 2, which represents a five-inch oscilloscope presentation, the crowding of the waveform at the right-hand end is probably mainly due to:

a. Sync amplitude control set too high.

b. An exponential sweep voltage.

c. Flyback time too great a percentage of total sweep time.

d. Lack of push-pull deflection voltage.

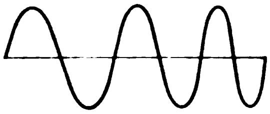


Figure 2

11. Explain, briefly, the operation of the two types of gas tubes.

Cold cathode type:

When B+ is applied to a gas tube, any positive ions present in the low gas pressure are attracted to the cathode where, by bombardment, large quantities of electrons are released, to enter into the ionizing process; a "bucket brigade" of gas atoms forms passing electrons along till they reach the plate, as Ip. (Handles relatively large current.)

Hot-cathode type:

Electrons surrounding the hot cathode are attracted toward the plate, but in the path they react with gas atoms, forming a low-resistance ionized path. These ions neutralize the space charge around the cathode, and permit large Ip. The effect, in some ways, is similar to having the plate extremely close to the cathode, without the disadvantages that would arise from this proximity.

12. d. The linearity of a saw-tooth voltage can be improved by:

a. Making the discharge time of the capacitor equal to the charge time.

b. Using only the discharge time.

c. Employing a very short RC time constant.

d. Allowing only a small portion of the total charge to be used.

e. Making the supply voltage very low.

13. Definite the following:

a. Firing potential:

A firing potential is the potential at which a gas tube, such as a neon tube, will start to conduct.

b. Deionizing potential:

Deionizing potential is the potential at which a gas tube will stop conducting. It is lower than the firing potential.

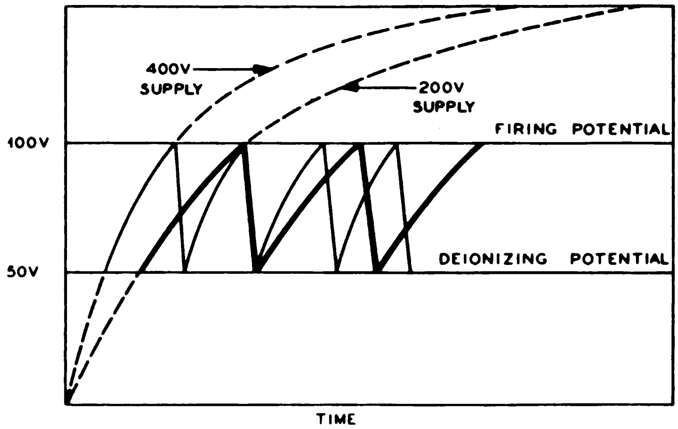


Figure 3

14. Use figure 3 above to, draw three cycles of the waveforms obtained from a simple neon-saw-tooth generator, having an ionizing potential of 100 volts and an extinction potential of 50 volts when supply voltages of 200 volts and 400 volts are used.

15. b . In the circuit below, the resistor, R, controls:

a. The discharge time of capacitor C.

b. The charging rate of capacitor C.

c. The amplitude of the saw-tooth generated.

d. The usable portion of the generated saw-tooth to 15% of maximum amplitude.

e. The charging rate of the source voltage.

16. c . In a gas tube of the cold-cathode type, conduction through the tube is made unidirectional by:

a. Proper choice of supply-voltage polarity.

b. Making the plate area physically larger than that of the cathode.

c. Making the cathode area physically larger than the plate area.

d. Making the plate and cathode areas of the tube essentially the same.

17. What is "flyback time"?

This is the portion of a cycle in which the spot on a cathode-ray tube is returning to its starting point.

18. c . An expanded sweep:

a. Shows a greater sweep time than does normal sweep.

b. Is produced by speeding up the rate of echo return to facilitate accurate ranging.

c. Allows improved ranging accuracy, since the sweep of the electron beam across the scope face is speeded up for part of the time.

d. Is accomplished by reducing the speed with which the electron beam moves across the face of the scope.

19. a . The bootstrap sweep circuit:

a. Serves primarily to improve sweep linearity.

b. Serves primarily to allow the use of faster sweep rates, which, thereby, improve ranging accuracy.

c. Is not a gated sweep generator.

d. None of the above is correct.

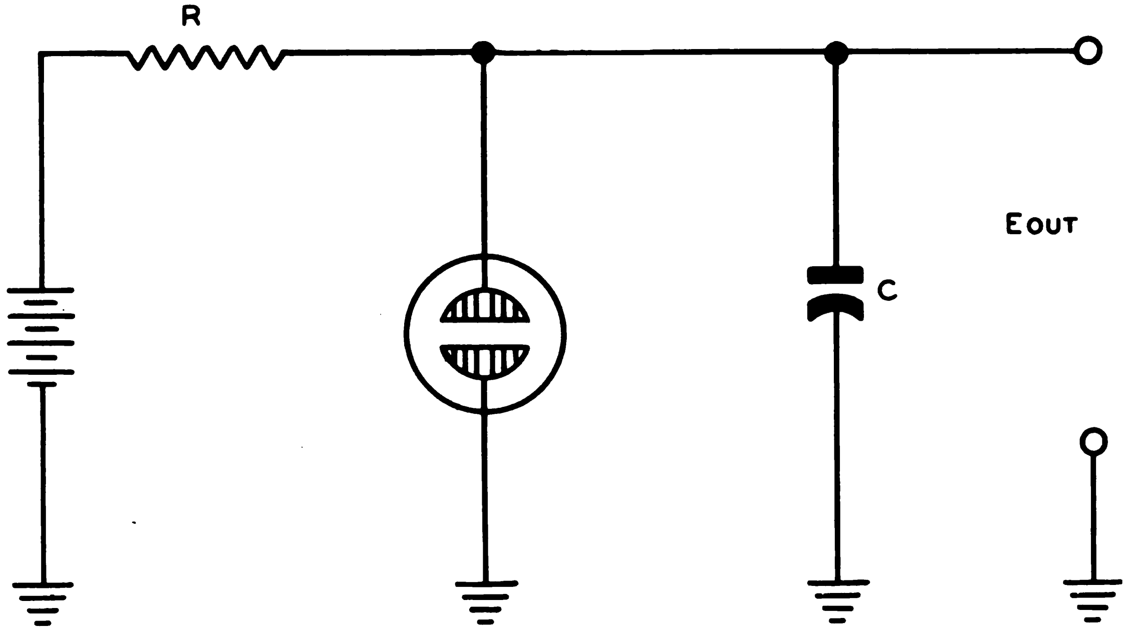


Figure 4

20. c . The step counter of a certain equipment is found to be counting at various ratios, both above and below its normal 5:1 ratio. The cause may be:

a. Charging capacitor varying in value above and below its normal value.

b. Series diode filament open.

c. Amplitude of input pulses varying widely, due to failure of limiting circuit.

d. Parallel diode filament open.

21. d . The step counter, when used with a blocking oscillator, is:

a. A type of square-wave-generator circuit.

b. A frequency-multiplier circuit.

c. A type of time-delay circuit.

d. A frequency-divider circuit.

22. c . If saturation limiting, with a low-amplitude input signal, is desired, it can be had by using a:

a. Low value of grid-leak resistance.

b. Low plate voltage and high screen voltage.

c. Low plate supply voltage and high plate-load resistance.

d. Large value of resistance.

23. c . The signal across a resistor in a short RC time constant circuit, when a sine wave voltage is applied, is:

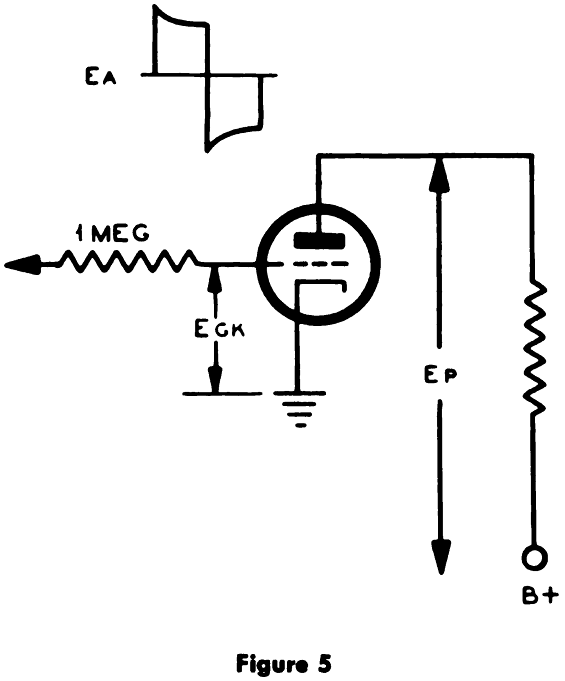
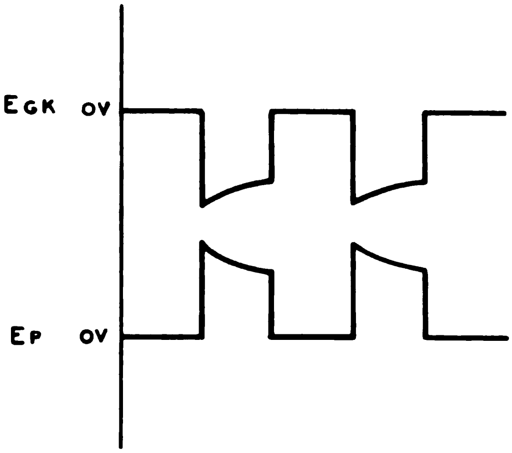


Figure 5



Suggested Drawing (Question 25)

a. A series of pulses.

b. An in-phase sine wave.

c. A phase-shifted sine wave.

d. A square wave.

e. A peaked wave.

24. c . A sync signal coupled into a free-running multivibrator:

a. Controls the output frequency by regulating the RC time constant of the multivibrator.

b. Controls the time duration of each of the pulse alternations.

c. Controls the output frequency of the multivibrator, being generally higher in frequency than the multivibrator natural frequency.

d. Controls the output frequency of the multivibrator, being slightly lower in frequency than the multivibrator natural frequency.

25. Referring to Figure 5, draw the waveforms of E_{gk} and E_p.

26. List three uses for a multivibrator.

a. As a source of square waves.

b. As an electronic switch.

c. As a means of obtaining frequency division.

d. To provide time or trigger delay.

LESSON PLAN No. 26

SUBJECT

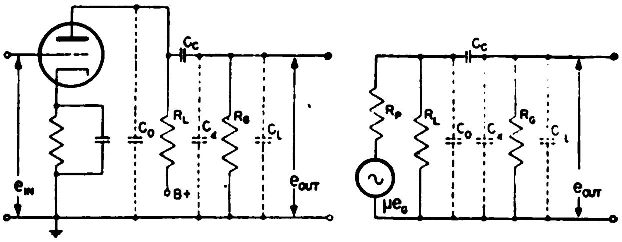
Video amplifier, cathode follower, and phase inverter.

OBJECTIVE

To describe the theory and application of these circuits.

MATERIAL REQUIRED

1. One-Shot Multivibrator Demonstration Unit.
2. Video Amplifier Demonstration Unit.
3. Cathode Follower Demonstration Unit.
4. Phase Splitter Demonstration Unit.
5. Audio signal generator.
6. Five-inch cathode-ray oscilloscope.



① ACTUAL CIRCUIT ② EQUIVALENT CIRCUIT

TL-7673A

Figure 1

INTRODUCTION

Video amplifiers are R-C coupled vacuum-tube circuits designed to amplify, with a minimum of distortion, the nonsinusoidal waveforms encountered in radar circuits.

The cathode follower is primarily an impedance-matching device having less than unity voltage gain, but capable of producing power gain. It is widely used both as a matching and as an isolating device.

A phase inverter is a circuit which produces an output voltage of opposite polarity to the input voltage. A paraphase amplifier, or phase splitter, produces two output signals of opposite polarity when a single input voltage is applied.

SUBJECT MATERIAL

Video Amplifiers

1. Review briefly the frequency-response characteristics of an uncompensated R-C amplifier.

a. Draw a single stage of an R-C coupled amplifier, explaining the physical significance of the capacitances C_d, C_o, and C_i, Figure 1.

b. Draw the low, medium, and high-frequency equivalent circuits for an R-C coupled amplifier. Discuss the effect upon amplification of C_c (at low frequencies), and of C_s (at high frequencies). Draw a curve illustrating the variation of amplification with frequency in R-C coupled amplifiers, and call attention to the reduction of amplification at both high and low frequencies. Show the approximate frequency range over which a flat response can be obtained. Figure (2) (3). $(C_s = C_o + C_d + C_i.)$

c. Recall to the class the various frequencies of which nonsinusoidal waveforms are composed (LESSON PLAN No. 2).

d. Discuss the types of distortion produced upon nonsinusoidal waveshapes by a conventional R-C amplifier. Demonstrate the effect of high-frequency attenuation and of low-frequency phase shift upon a square wave.

(1) Set up the classroom demonstration equipment.

(2) Apply the output of the One-Shot Multivibrator Demonstration Unit through a voltage divider network which will reduce it to an amplitude that can be presented directly upon the screen of the oscilloscope.

(3) Call attention to the sharp corners and nearly flat tops of these square waves.

(4) Remove the multivibrator output from the vertical deflection plates of the oscilloscope, and connect it to the input of the Video Amplifier Demonstration Unit, using it as a conventional R-C coupled amplifier. Connect the output of the Video Amplfiier Demonstration Unit directly to the vertical plates of the oscilloscope.

(5) Note that the leading edges of the waveforms appearing on the screen are rounded when the signal generator is set at a high audio frequency.

(6) Tune the audio-frequency generator to 30 cycles and point out that the resulting waveforms exhibit flattened peaks.

(7) Show that these types of distortion may lead to incorrect analysis of the occurrences in the radar circuit under observation.

2. Show how high-frequency compensation can be applied to a conventional R-C amplifier, in order to extend its high-frequency response to a point where it will not cause rounding of the leading edges of a square wave.

a. Draw a shunt compensation circuit on the blackboard, and show how it operates to reduce high-frequency attenuation, Figure 4.

b. Draw a series compensation circuit, and show how it reduces high-frequency attenuation, Figure 5.

c. Draw a shunt-series compensation circuit, and explain how such an arrangement can be combined in one circuit, Figure 6.

3. Discuss how low-frequency compensation can be used to maintain a well-shaped square wave.

a. Draw a low-frequency compensation circuit, and explain its operation, Figure 7.

b. Explain that a very large value of cathode bypass capacitor is required for good low-frequency compensation.

4. Draw the frequency response curve of a video amplifier, and compare its bandwidth to that of a conventional R-C amplifier, Figure 8.

5. Show the class why video amplifiers normally have a very low voltage gain.

a. It is necessary to reduce the plate-load resistor to a value sometimes as low as 1000 ohms, in order to eliminate high-frequency attenuation.

b. However, high gain in an amplifier depends upon the use of a large plate load resistor. Hence, using the 1000-ohm resistor results in a decrease in voltage gain.

c. To remedy this condition, it is customary to use pentode tubes, which produce satisfactory gains when a low value of load resistor is used. Give, as examples, the 6AC7, the 6BC5, and similar pentodes.

6. Emphasize that extreme precautions must be taken to avoid unstable operation when more than two video amplifiers derive their plate supply from the same source. Point out that this limitation reduces the possible voltage gain to a fairly low value, unless precautions are taken that will permit several stages to be used in cascade. The normal voltage gain of a video amplifier stage is somewhere between two and twenty.

7. Conduct a short review in the form of an oral quiz on the subject of video amplifiers.

Cathode Followers

1. Review briefly the use of negative feedback to reduce distortion.

2. With the aid of a current feedback amplifier circuit diagram, review the use of an unby-passed cathode resistor to produce negative feedback.

3. Draw and explain the operation of a conventional cathode follower, showing how degeneration takes place; explain the reason why a cathode follower can be used to match a high impedance to a low impedance.

4. By use of the figure show that output and imput voltages are in phase.

5. Set up the demonstration unit equipment, and feed the output of the audio-frequency oscillator to the input of the Cathode Follower Demonstration Unit. Use the oscilloscope to demonstrate that the output and input voltages are in phase.

6. Using a cathode follower equivalent circuit, develop the formula for voltage gain, showing that it is always less than unity.

7. Draw and explain the equivalent output circuit of the cathode follower. Develop the formula for its output impedance.

8. With the equipment set up as in paragraph 5, above, measure the input and output voltages on the oscilloscope, to show that the output is less than the input.

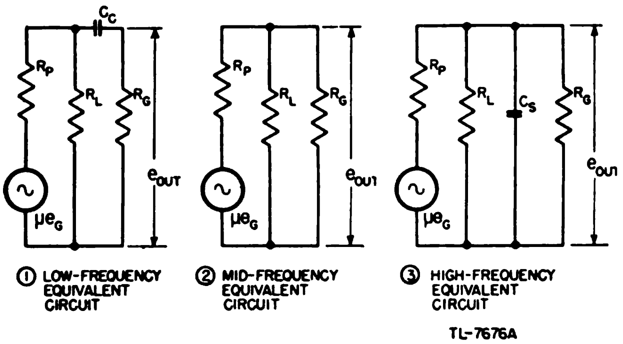
9. Review briefly the necessity for impedance matching in order to obtain maximum power transfer, emphasizing that the cathode follower is particularly adapted for this purpose. Discuss the desirability of using high-transconductance tubes in a cathode-follower circuit, in order to obtain a low output impedance, resulting in higher upper frequency limits.

10. Describe the distortion produced by cutoff limiting. Explain the operation of a cathode follower, with reduced grid bias, to decrease cutoff limiting, Figure 9.

11. Conduct a review in the form of an oral quiz covering the subjects discussed in connection with the cathode follower.

Phase Splitters

1. Define the term "phase inversion."



① LOW-FREQUENCY EQUIVALENT CIRCUIT ② MID-FREQUENCY EQUIVALENT CIRCUIT ③ HIGH-FREQUENCY EQUIVALENT CIRCUIT

Figure 2

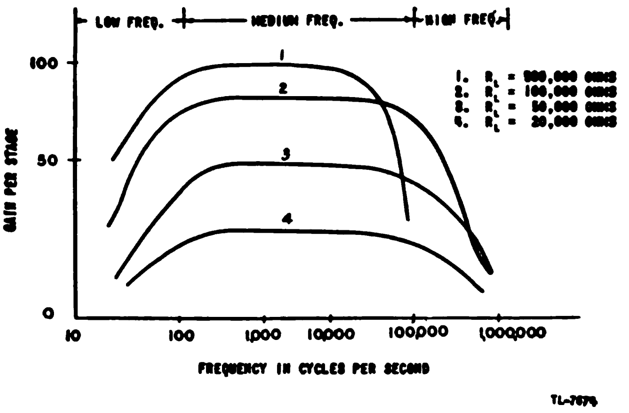
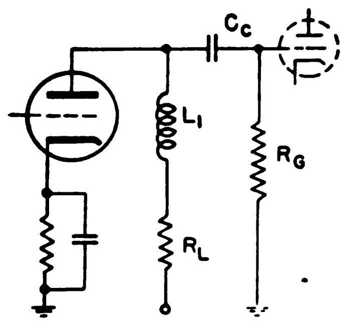
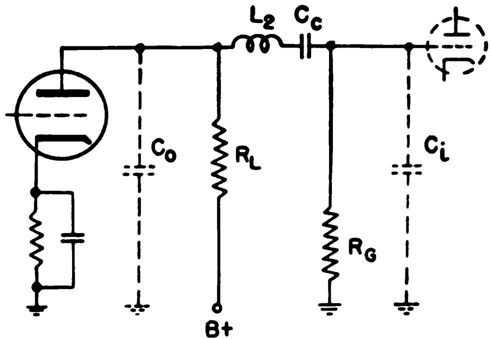


Figure 3



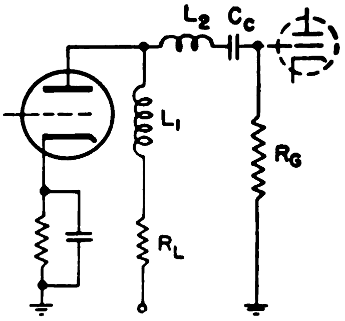
① SHUNT COMPENSATION

Figure 4



② SERIES COMPENSATION

Figure 5



③ SHUNT-SERIES COMPENSATION

Figure 6

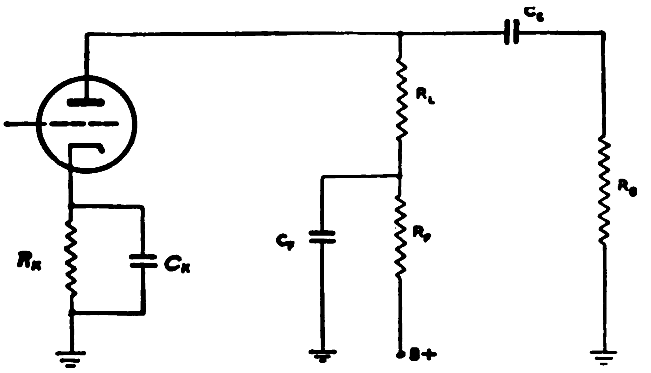


Figure 7

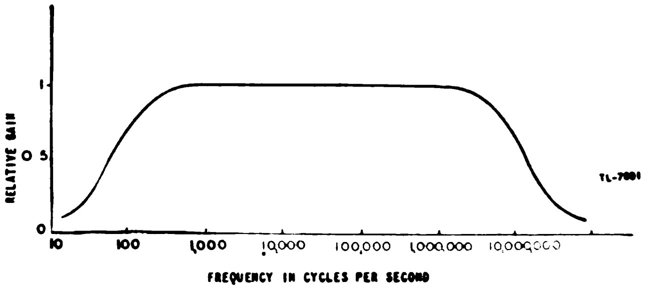


Figure 8

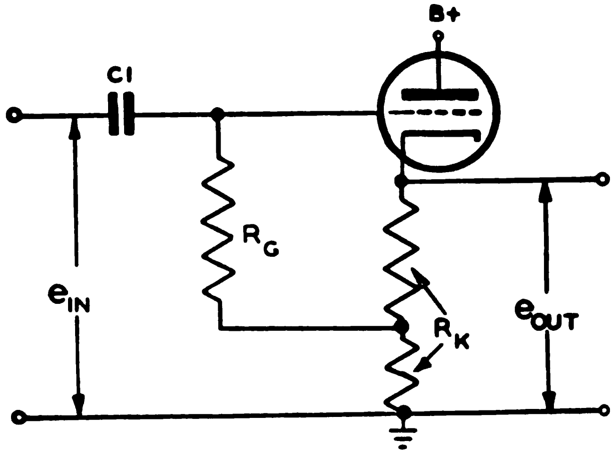


Figure 9

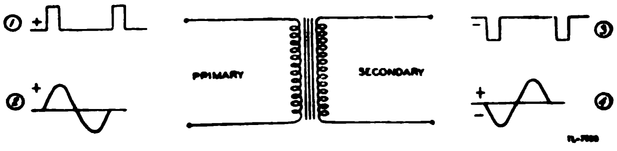


Figure 10

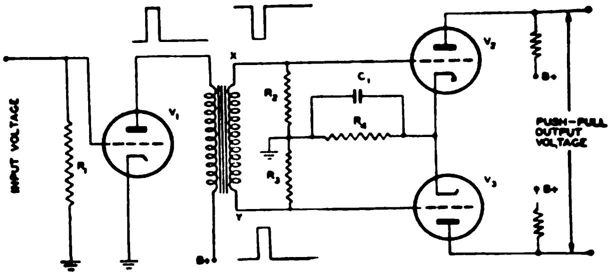


Figure 12

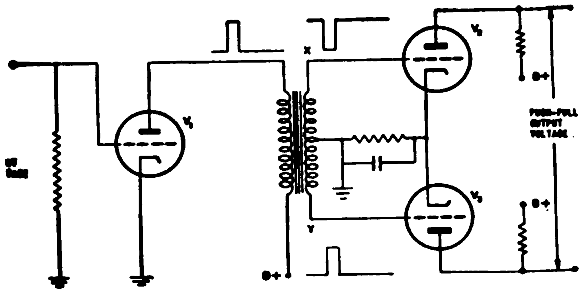


Figure 11

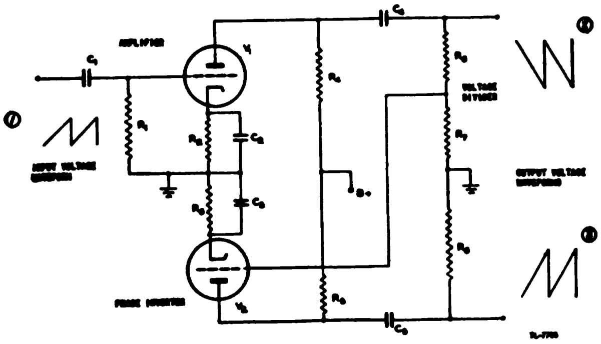


Figure 15

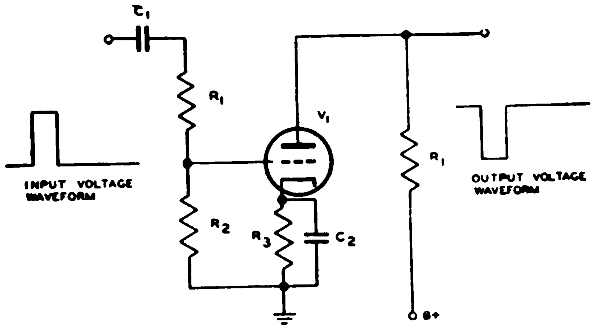


Figure 13

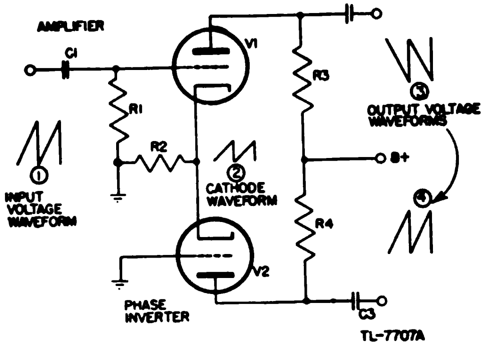


Figure 16

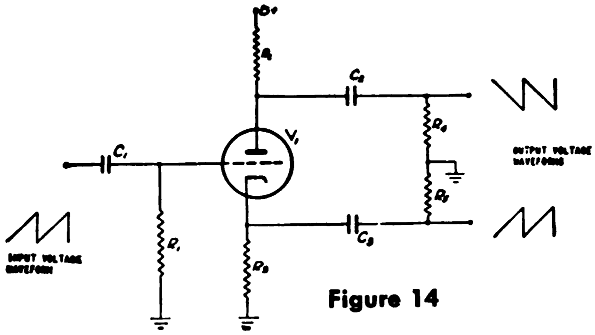


Figure 14

2. Show how a transformer produces phase inversion, Figure 10.

3. Explain how a transformer with a center-tapped secondary can produce two output signals of equal amplitude and opposite polarity, and how it may be used to drive a push-pull amplifier, Figure 11.

4. Discuss the operation of a voltage-divider circuit used to provide an effective center tap. Show how a push-pull output can be obtained without center tapping the transformer secondary, Figure 12.

5. Review the phase-inversion action of a vacuum-tube amplifier.

6. Explain the necessity for reducing the gain to unity when the input and output voltages are to be combined to form a push-pull output. Indicate that a voltage-divider circuit is used to reduce the gain to unity. Derive the expression (R1+R2)/R2, showing that it is the gain of the circuits, Figure 13.

7. Define the term "paraphase amplifier." Analyze the circuit of a biased single-tube paraphase amplifier, using waveforms. Explain that for an approximately symmetrical output, R2 must be equal to R3, Figure 14.

8. Discuss a phase-splitter circuit which employs a voltage divider. With waveforms, explain the circuit operation in detail. Show the purpose of the voltage-divider network, pointing out that for a symmetrical output, R6+R7/R7 equals the gain of the amplifier, and (R6+R7) equals R8, Figure 15.

9. Discuss the cathode-coupled paraphase amplifier and phase inverter, Figure 16.

   a. Show how a signal on the grid of V1 produces a signal of opposite polarity on the grid of V2.

   b. Show the relative polarity of the output voltages at the plates of V1 and V2.

   c. Explain that a symmetrical output is obtained only when the voltage across R2 is one-half the input voltage across R1.

10. Conduct a short review in the form of an oral quiz covering the section of the lecture concerning phase splitters.

CONCLUSIONS

Video amplifiers must have a wide range of uniform amplification. This is accomplished at the upper frequency limit by minimizing stray capacitance, and compensating for that which cannot be avoided. At the lower frequency limit, the coupling and cathode capacitors are made as large as is practicable.

The cathode follower is a degenerative circuit in which the feedback is obtained by means of an unbypassed cathode resistor. Essentially, the circuit is an impedance-matching device exhibiting a voltage gain of less than unity, but displaying an appreciable power gain.

The phase inverter produces an output voltage of opposite polarity to the input voltage without distortion.

ORAL QUIZ

1. Why is it impractical to use a conventional R-C coupled amplifier for the amplification of square waves?

2. Explain briefly the reasons for the decrease in gain of an R-C-coupled amplifier at high and at low frequencies.

3. What characteristics of a cathode follower make it useful as a power transforming device between a high-impedance source and a low-impedance load?

4. What is the maximum gain (in percent) that can be obtained from a cathode follower?

5. What is the purpose of a paraphase amplifier?

6. In the circuit of paragraph 8, under Phase Splitters, the voltage gain of the amplifier, V2, is 20, and R6 = 190,000 ohms. What is the value of R7?

LESSON PLAN No. 27

SUBJECT

The cathode-ray tube.

OBJECTIVE

To explain the theory of operation of the cathode-ray tube.

MATERIAL REQUIRED

1. Five-inch cathode-ray oscilloscope.
2. Sample electron guns.
3. Voltmeter.

INTRODUCTION

The cathode-ray tube is a special type of vacuum tube consisting of an electron gun that projects a narrow beam of electrons along the axis of the tube, a means of deflecting the beam, and a fluorescent screen to indicate the position of the beam. In maintenance work, this tube is used in oscilloscopes to observe the waveforms being developed in the equipment. In radar systems, the cathode-ray tube is employed as an indicator which presents information about the location of radar targets.

SUBJECT MATERIAL

1. Discuss the properties of the electron beam, including:

a. A brief review of electron motion in an electrostatic field.

b. The general characteristics of the electron, regarding mass and charge.

2. Draw a typical electrostatic cathode-ray tube, explaining the physical structure of each component part, and its use, Figure 1.

3. Using diagrams of the elements of a cathode-ray tube, give a step-by-step explanation of the action of the electron beam from the instant the electrons are emitted from the cathode until they strike the screen.

a. With the aid of a drawing, explain the action of the grid in concentrating electrons into a beam, Figure 2.

b. Draw the light analogy to electron-beam-focusing, Figure 3.

c. Draw and analyze the electrostatic field between the first and second anodes. Explain the focusing properties of this field, Figure 4.

d. Explain how electrostatic deflection of the electron beam is accomplished in the cathode-ray tube. Illustrate how deflection sensitivity depends upon the distance of the screen from the deflecting plates. Discuss the advantages of divergent deflection plates.

e. Analyze the behavior of the electron beam as it strikes the screen of a cathode-ray tube:

(1) Explain how the luminescent properties of the screen enable it to convert energy from the beam into visible light.

(2) Show how the persistence of vision and the phosphorescence of the screen make the traces appear in a continuous line, although the spot rests upon the screen at only one point at a time.

(3) Explain the dual purpose of the aquadag and the intensifying ring.

(4) Discuss the difference between long-and-short-persistence screens. Point out their individual advantages, and give several examples of the applications of each.

(5) Discuss the nomenclature of cathode-ray tubes (e.g., 5CP1).

(6) Distribute among the students several electron-gun structures, and briefly discuss their theory of operation again, as a review.

4. Set up the five-inch oscilloscope, and show how its deflection sensitivity can be determined:

a. Turn on the scope, and adjust its controls so that a spot can be observed in the exact center of the screen.

b. Turn off the scope, and connect a variable a-c voltage source directly to the vertical deflection plates, using the rear panel connections on the scope. (The Dumont 274A scope is used for this demonstration.) Also, connect a voltmeter to the output of the voltage source.

c. Turn on the scope again, and turn on the voltage source.

d. Adjust the voltage control until the spot appears in the exact center of the scope screen, and the voltmeter reads zero. The spot should again be at the center of the scope.

e. Adjust the voltage control until the spot on the scope has moved one inch.

f. Read the voltage required to produce this deflection.

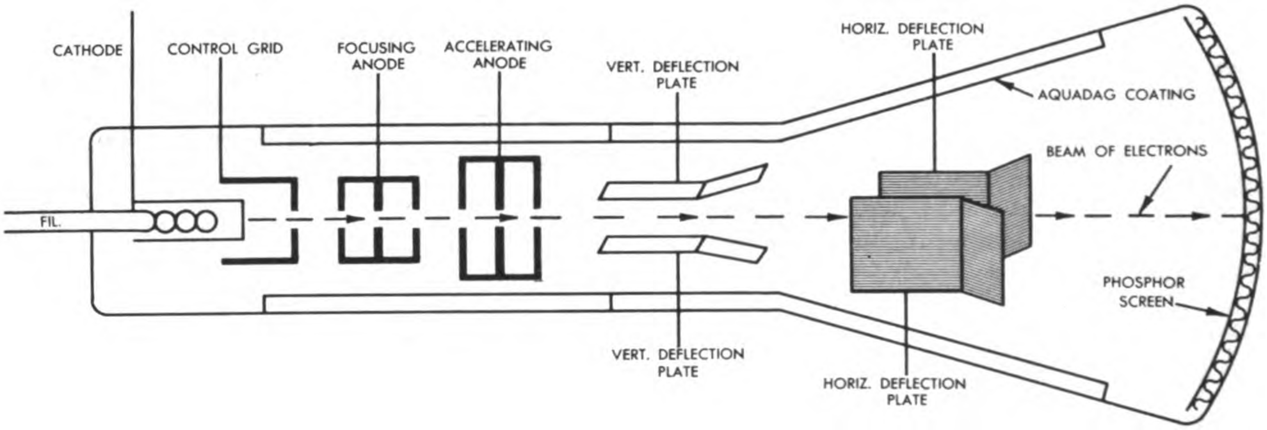


Figure 1

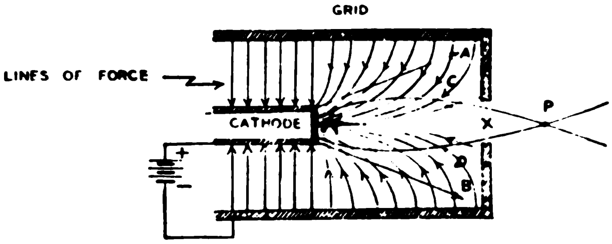


Figure 2

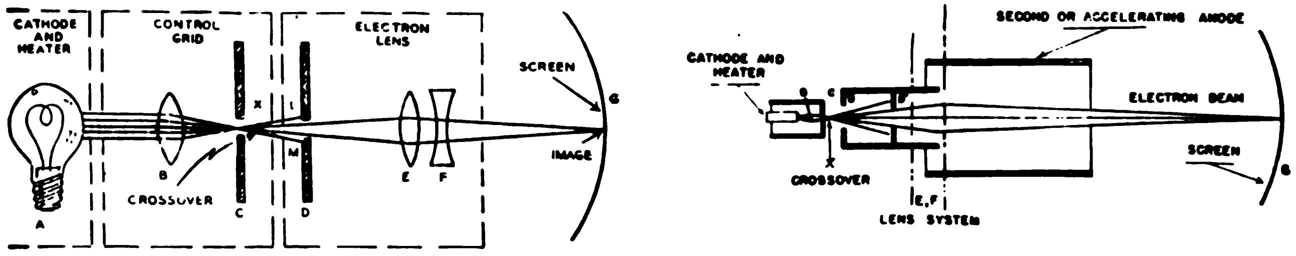


Figure 3

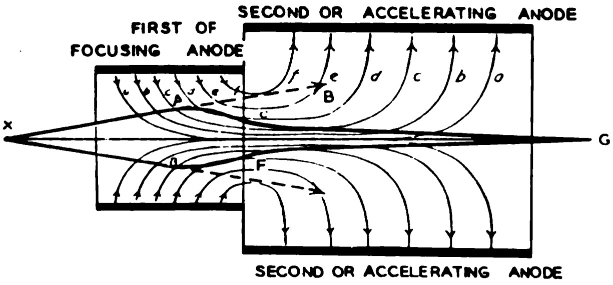


Figure 4

g. Calculate the vertical deflection sensitivity by the formula: Vertical deflection sensitivity

$$= \frac{\text{volts applied}}{\text{deflection distance in inches}}.$$

h. Adjust the deflection voltage control for greater output. Observe the distortion produced as the spot reaches the edge of the screen. Explain this distortion.

i. Turn off and disconnect the equipment; restore the rear panel of the scope to its original connections.

j. Connect the rear panel so as to apply the variable a-c voltage source to the horizontal deflection plates.

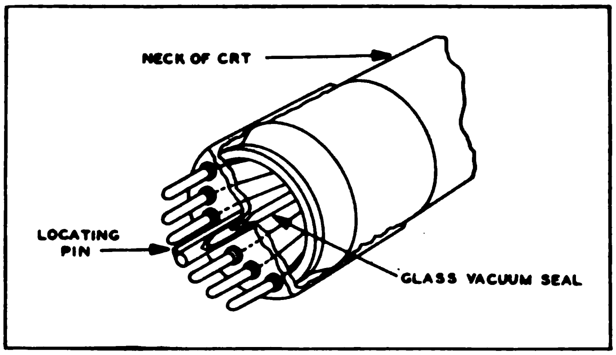
k. Repeat the procedure given for measurement of vertical deflection by applying the voltage to the horizontal plates. Explain why the horizontal and the vertical deflection sensitivity are different.

CONCLUSIONS

Because of its small mass, an electron beam will respond to the forces applied to it in the form of the electrostatic field, even when the field is changing at very high frequencies. This principle is employed in the cathode-ray tube, which finds its greatest application in cathode-ray oscilloscopes and in radar indicating circuits.

ORAL QUIZ

1. Explain the function of the grid, first anode, and second anode in the operation of the electron gun.
2. What would happen if the electrons which strike the screen were allowed to pile up there? How is this condition avoided?
3. Explain why there is interaction between the focusing and the intensity controls.
4. Which element of the electron gun controls beam intensity?
5. Which element of the electron gun controls the focusing of the beam?



Construction of Cathode Ray Tube Base

LESSON PLAN No. 28

SUBJECT

The cathode-ray oscilloscope.

OBJECTIVE

To explain the function of each oscilloscope control. To demonstrate the potentialities of the oscilloscope as a test instrument.

MATERIAL REQUIRED

1. Five-inch cathode-ray oscilloscope.
2. Audio signal generator (2 required).
3. Phase Splitter Demonstration Unit.
4. Power Supply Demonstration Unit.

INTRODUCTION

The oscilloscope is one of the most important and reliable test instruments used in the maintenance and repair of electronic equipment. It is especially valuable because it permits a visual examination of various electronic phenomena that cannot otherwise be measured accurately.

SUBJECT MATERIAL

1. Set up an oscilloscope, and explain thoroughly the adjustment of the controls on its front panel. Cover the following:

a. Intensity and focusing controls.

b. Horizontal and vertical positioning.

c. Sweep-frequency selector, coarse and fine adjustments.

d. Signal input points.

e. Sync signal selection and amplitude controls.

f. Horizontal and vertical amplifier controls, and attenuator for large signals.

g. Test signal point.

h. Any other controls peculiar to the scope being used.

2. Show that any a-c signal applied to the horizontal deflection plates will produce a sweep, but that a linear sweep is desired in most cases. Point out that a saw-tooth waveform is necessary to provide a linear sweep. Explain why a linear time base is desirable.

3. Explain the limitations of an oscilloscope:

a. Maximum input signal is limited by the voltage rating of the input capacitor. (Describe the use of a voltage divider.)

b. The amplifiers impose frequency limitations that must not be exceeded.

c. The frequency change of the sweep generator is limited.

d. The input impedance and capacitance must be considered.

4. Discuss the oscilloscope as a measuring device:

a. As a d-c voltmeter.

b. As an a-c voltmeter.

5. Show how frequency measurements can be made by means of Lissajous figures.

a. Make both horizontal and vertical voltages of the same amplitude, in order to simplify measurements.

b. Explain how to determine frequency, using Lissajous figures of various frequency ratios, Figures 1, 2, 3.

6. Teach the method of phase-angle measurement by using Lissajous figures, Figure 4.

CONCLUSIONS

Even though the oscilloscope may be used for measuring the frequency magnitudes of voltage, and for observing different waveforms applicable to electronic circuits, it does have limitations. Every technician should appreciate the usefulness of this valuable instrument.

ORAL QUIZ

1. Explain the use of each front panel control.
2. Why is it necessary to use a voltage divider in some oscilloscope applications?
3. Explain the use of Lissajous figures in measuring frequency.

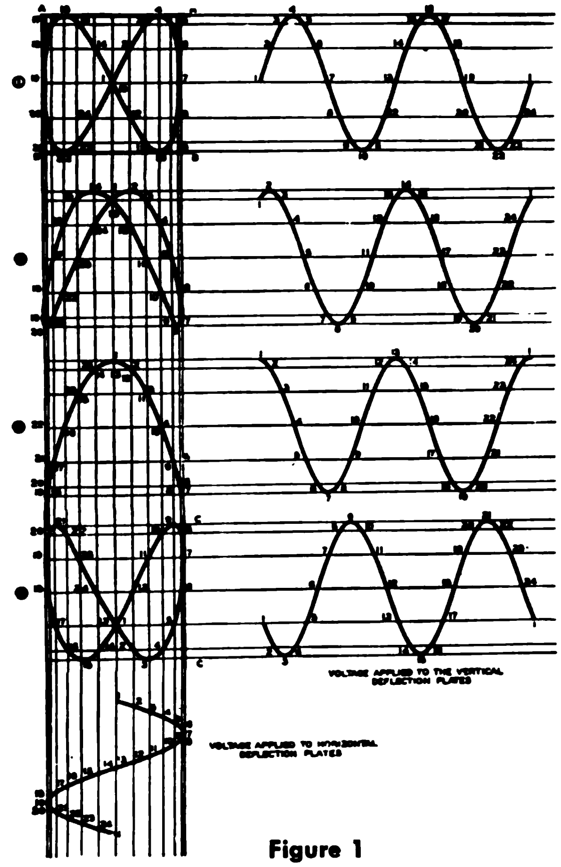

VOLTAGE APPLIED TO THE VERTICAL DEFLECTION PLATES
VOLTAGE APPLIED TO HORIZONTAL DEFLECTION PLATES

Figure 1

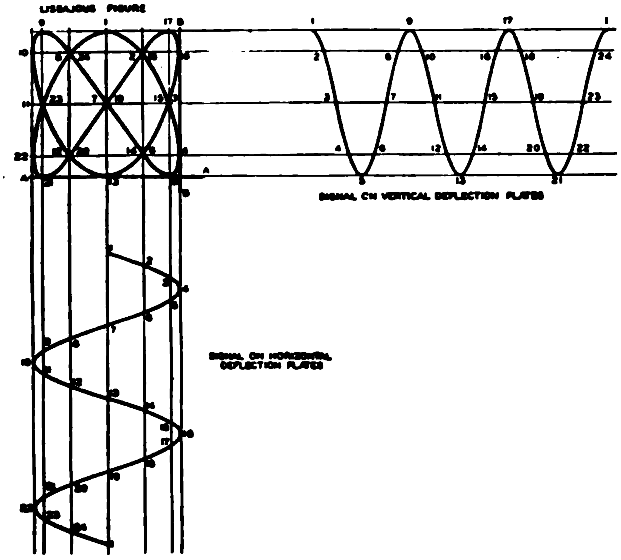

LISSAJOUS FIGURE
SIGNAL ON VERTICAL DEFLECTION PLATES
SIGNAL ON HORIZONTAL DEFLECTION PLATES

Figure 2

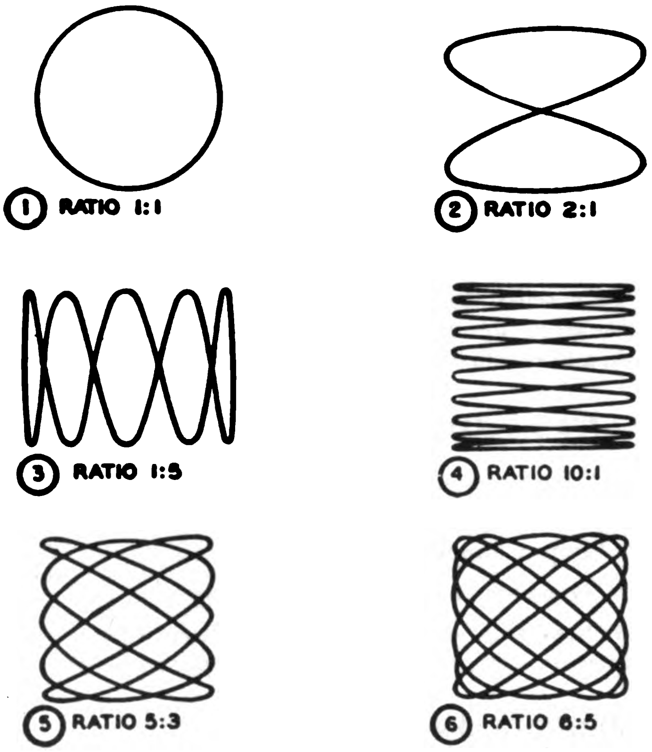

① RATIO 1:1
② RATIO 2:1
③ RATIO 1:5
④ RATIO 10:1
⑤ RATIO 5:3
⑥ RATIO 8:5

Figure 3

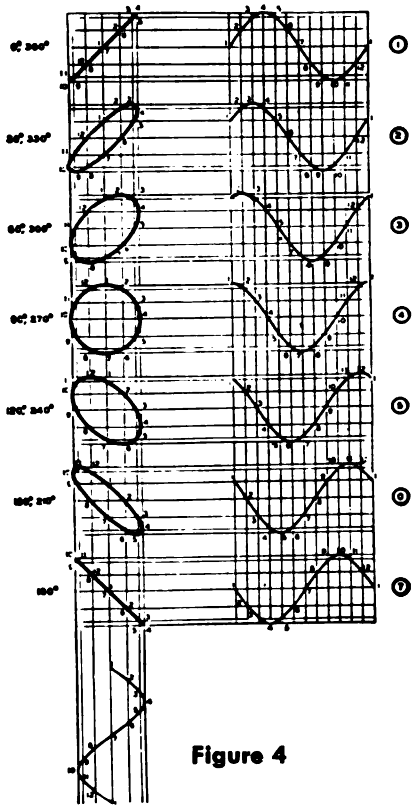


Figure 4

LESSON PLAN No. 29

SUBJECT

Oscilloscope circuits.

OBJECTIVE

To discuss the combined actions of the sweep generator, horizontal amplifier, blanking circuit, and synchronizing circuits of an oscilloscope.

MATERIAL REQUIRED

1. Thyratron Saw-tooth Generator Demonstration Unit.
2. Power Supply Demonstration Unit.
3. Five-inch cathode-ray oscilloscope.
4. Schematic diagrams of the Dumont 208 oscilloscope (diagram on page 94) (1 per student).

INTRODUCTION

Most oscilloscopes use basically the same circuits. The Dumont 208 oscilloscope will be used in this demonstration to familiarize the class with these essential circuits. The time-base (sweep) generator, the horizontal and vertical amplifiers, and the positioning controls of this oscilloscope will be considered.

SUBJECT MATERIAL

1. Describe the time-base generator circuits used in this scope:

a. Conduct a short review of the thyratron saw-tooth generator, using the Thyratron Saw-tooth Generator Demonstration Unit.

b. Distribute copies of the oscilloscope schematic diagram to the class.

c. Analyze the time-base circuit.

d. Call attention to the frequency range of the sweep generator in this oscilloscope.

2. Explain the action of the synchronizing circuits by first drawing on the board the apparent motion of oscilloscope patterns on a screen, and then a schematic diagram of the thyratron sweep circuit, with provisions for synchronization. Show also the action of the synchronizing signal, and the distortion of sweep resulting from too much synchronizing voltage.

3. Explain the action of the horizontal deflection amplifier:

a. Show how gain is controlled.

b. Explain why a push-pull deflection amplifier is used, in preference to a single-ended amplifier.

c. Explain the phase-splitter circuit used in the oscilloscope.

4. Explain the action of the blanking circuit:

a. Show why blanking is necessary.

b. Analyze the circuit by which the blanking pulse is developed.

5. Explain the horizontal positioning controls used in this scope, discussing and illustrating both unbalanced and push-pull deflection, Figure 2, Figure 3.

CONCLUSIONS

The desired output from a saw-tooth generator is a voltage whose amplitude rises linearly with time until it reaches its maximum value, then returns very quickly to its starting value.

The horizontal deflection amplifier must not distort the saw-tooth waveform.

The action of the blanking circuit removes the back trace, which would otherwise appear on the screen.

The synchronizing circuit enables the signal frequency to control the sweep frequency to some simple multiple.

ORAL QUIZ

1. What is the function of R32 in the sweep-generator circuit of the Dumont 208 oscilloscope?
2. Why are thyratrons, rather than neon bulbs, used for saw-tooth generators?
3. Why are push-pull circuits used, rather than a single-ended amplifier?
4. What effect will the horizontal positioning control have upon the gain of tubes V10 and V11 in the phase-inverter section? Explain.

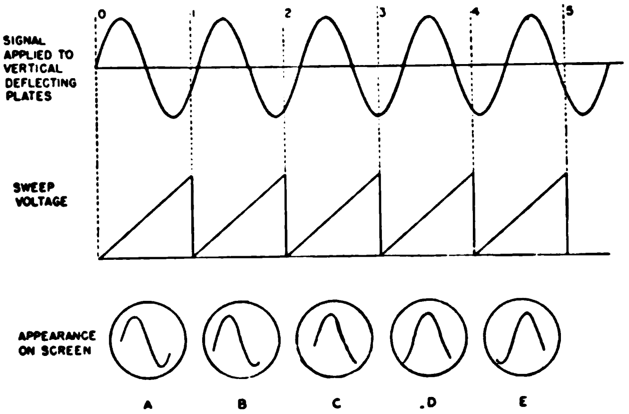


Figure 1

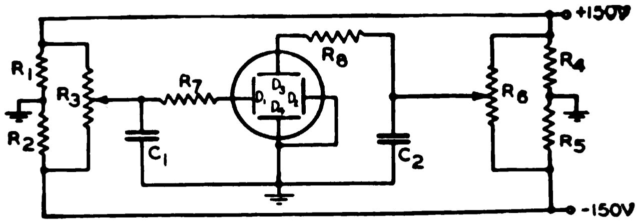


Figure 2

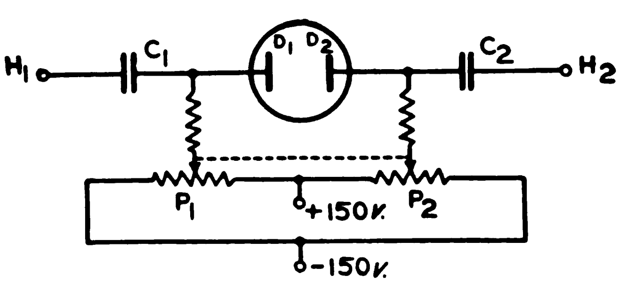


Figure 3

LESSON PLAN No. 30

SUBJECT

Oscilloscope vertical amplifiers and power supply.

OBJECTIVE

To teach the theory and operation of the vertical amplifier circuits and the power supply used in an oscilloscope.

INTRODUCTION

To obtain a true picture of the input waveforms, a vertical amplifier having excellent frequency characteristics must be used. The power supply must provide well-filtered d.c. over the proper ranges of voltage.

As an example of practical circuits used in oscilloscopes, the class will study the circuits used in the Dumont 208 oscilloscope (See page 94).

SUBJECT MATERIAL

The following discussion is based on the circuit of the Dumont 208 oscilloscope.

1. The video-frequency amplifier:

a. List the requirements of a good vertical amplifier for an oscilloscope:

(1) High gain.

(2) Excellent frequency response.

(3) Absolute stability.

(4) Illustrate the distortion of a square wave by improper amplification.

b. Explain the necessity for, and the function of, the switch marked "25V RMS-250V RMS."

(1) Refer to the diagram of the vertical-deflection amplifier.

(2) Explain the method by which very large signals (greater than 250v, r.m.s.) may be handled.

c. Explain the function of the cathode follower used as the input stage of the vertical amplifier.

(1) Refer again to the vertical-deflection-amplifier drawing.

(2) Explain how the gain control of the Dumont 208 scope operates in connection with the cathode-follower circuit.

d. Analyze the operation of the two-stage video amplifier (V1 and V2).

(1) Use the vertical-deflection-amplifier drawing.

(2) Discuss high-and-low-frequency compensation, as used in these circuits.

(3) Call attention to the frequency range of these amplifiers.

e. Discuss and analyze the video amplifier output stage (cathode follower V4):

(1) Refer to the diagram of the vertical-deflection amplifier.

(2) Explain why R17 is returned to the −280v tap of the power supply.

(3) Call attention to the similarity of operation between the vertical positioning control and the horizontal positioning control previously studied.

2. The power supply.

a. Give a general description of the power-supply requirements of an oscilloscope.

b. Explain why the oscilloscope anode is grounded, while the output terminal of the power supply is held negative with respect to ground.

c. State that the power supply of the Dumont 208 oscilloscope will be used as an example of practical circuits. Discuss:

(1) The schematic diagram of this power supply.

(2) The action of the +155v regulated voltage supply.

(3) The action of rectifier tubes V13, V14, and V15 of the Dumont 208.

3. Call attention to the interlock safety switch.

4. Note the application of +280 volts to the collector ring. Recall the function of this collector ring.

CONCLUSIONS

The characteristics of the vertical amplifier are high gain, broad frequency response, and absolute stability.

The oscilloscope power supply produces a wide range of voltages, well filtered, to prevent interaction between stages.

ORAL QUIZ

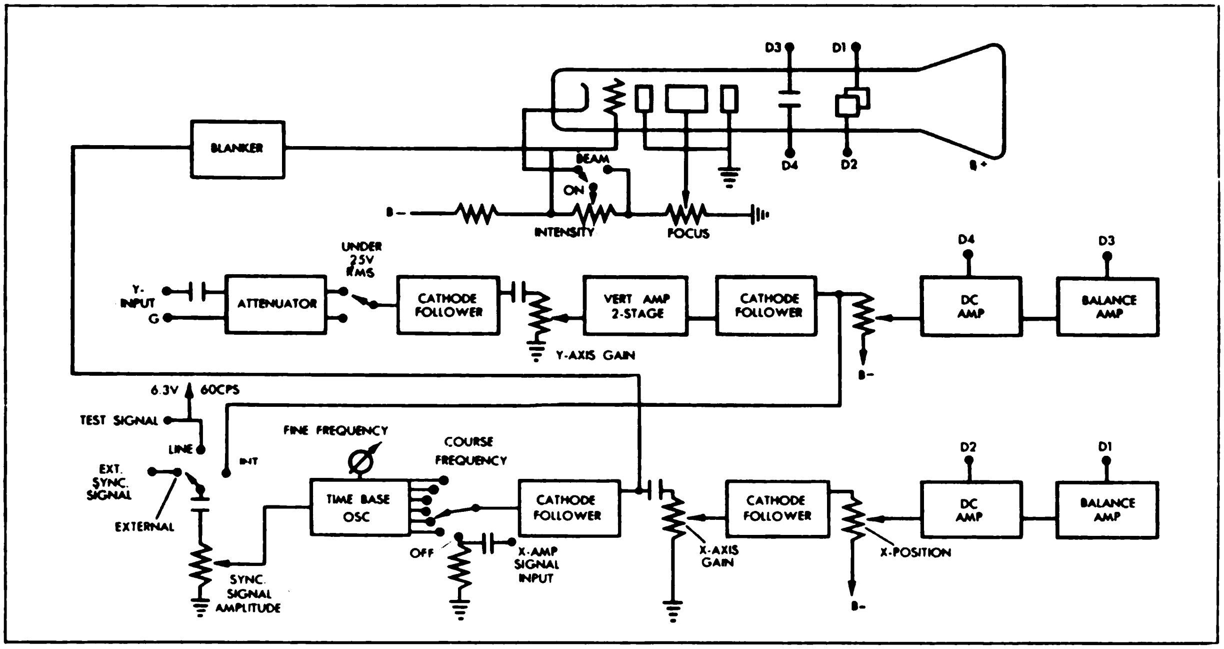
1. Explain the action of the compensated circuits (V3 and V4) in the video amplifier.

2. What are the frequency limits of the vertical amplifier?

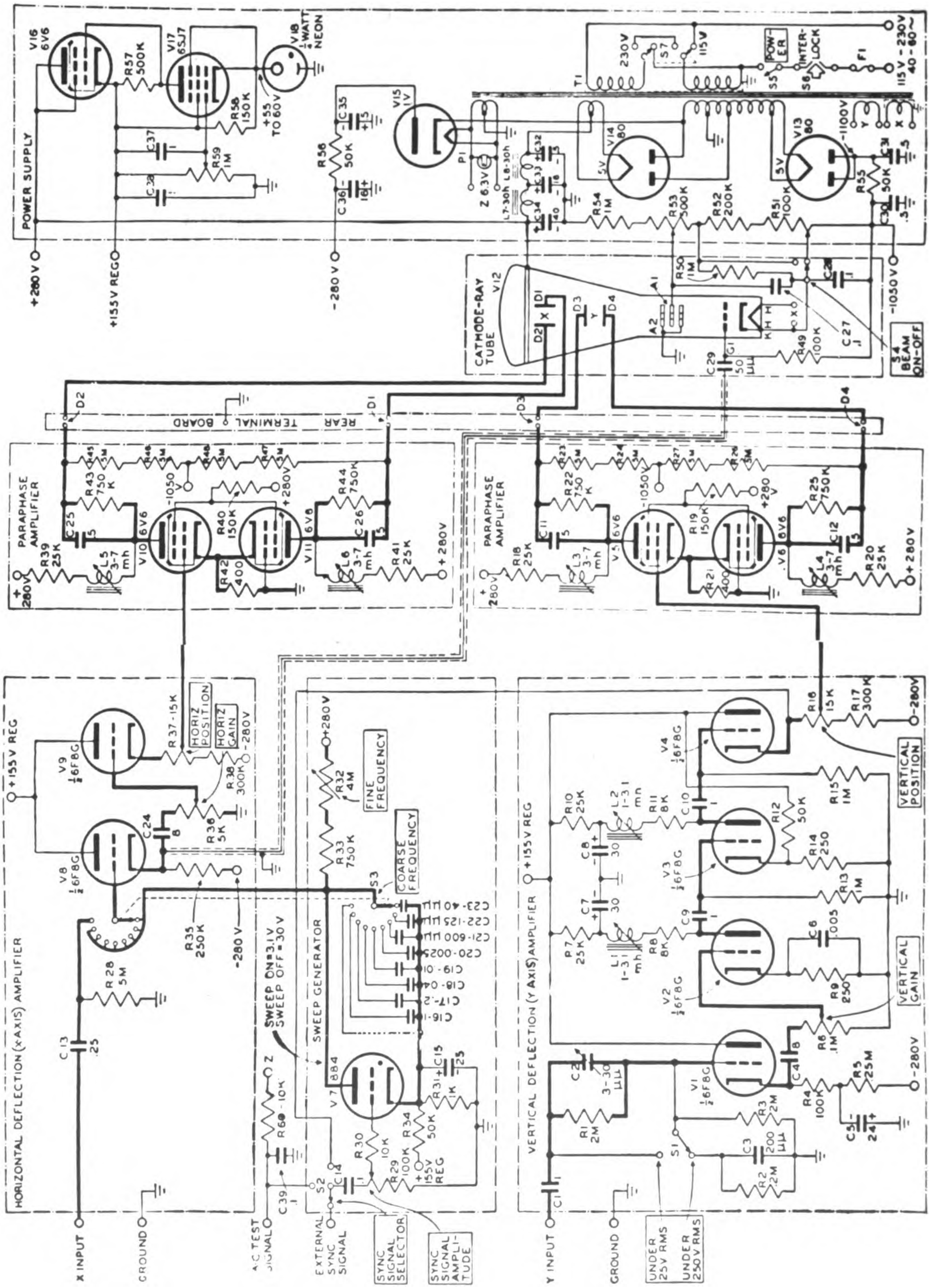
3. Explain the action of the vertical positioning control, R16.

4. Explain why the cathode of the cathode-ray tube is maintained at −1050v.

5. Explain the operation of the +155v regulated power supply.



Functional Block Diagram of DuMont Oscillograph



DuMont type 208 Electrostatic Cathode-Ray Oscilloscope

SECTION____________

ADVANCED ELECTRONIC CONCEPTS AND CIRCUITS

EXAMINATION No. 7

PART 1—CLOSED BOOK SECTION

NAME________________________ **GRADE**________________________

DATE________________________ **TIME ALLOTTED**________________________

INSTRUCTIONS

1. Do not raise this cover page until told to do so by the instructor.
2. If you need help with any particular question, raise your hand, and the instructor will come to you.
3. Perform any necessary calculations on the examination sheet.
4. Make sure that your name, section, and the date are entered in the spaces provided.
5. REFERENCE TEXTS OR NOTEBOOKS MAY NOT BE USED FOR THIS PART OF THE EXAMINATION.

SAMPLE

COVER

PAGE

EXAMINATION No. 7

1. b, e . If the bias voltage on the control grid of a cathode-ray tube is made less negative, two of the following effects will occur:

(Choose all correct answers.)

a. The number of electrons in the beam will be decreased, reducing the brilliance of the trace.

b. The crossover point will be shifted, resulting in a defocusing of the trace at the face of the tube.

c. The effect of the deflecting plates will be reduced, reducing the amount of deflection.

d. The velocity of the electron beam will be decreased, decreasing the brilliance of the trace.

e. The number of electrons in the beam will be increased, increasing the brilliance of the trace.

2. d . In a cathode-ray tube, the focusing is adjusted by varying the voltage applied to:

a. The aquadag coating.
b. The second anode.
c. The accelerating anode.
d. The first anode.

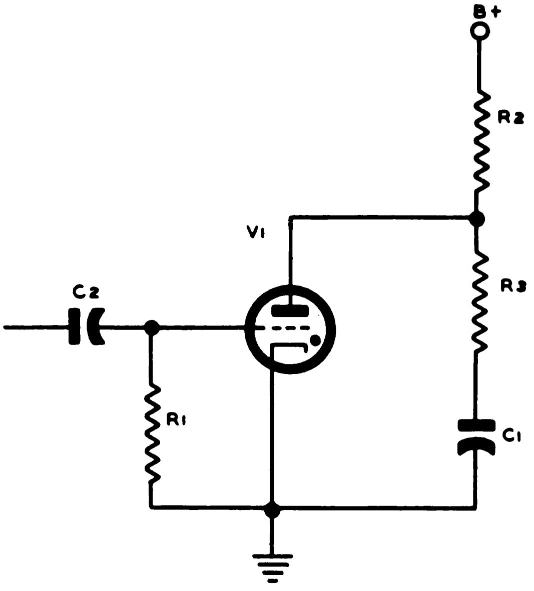
3. a . The vertical-deflection sensitivity of a given electrostatic cathode-ray tube is usually greater than the horizontal-deflection sensitivity, because:

a. The vertical-deflection plates are further from the screen than the horizontal-deflection plates.

b. The vertical-deflection plates are nearer to the screen than the horizontal-deflection plates.

c. The vertical-deflection plates are usually larger in area than the horizontal-deflection plates.

d. The horizontal-deflection plates are placed closer to each other than the vertical-deflection plates.



Suggested Drawing for Question 9

4. c, e . In an electrostatic cathode-ray tube which contains an accelerating anode, the two functions of the aquadag coating are:

(Choose all correct answers.)

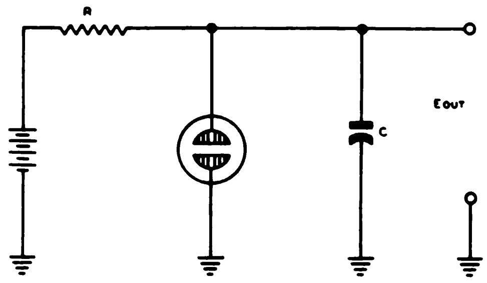
a. To keep the light emitted from the screen from reflecting back into the tube.

b. To keep the electron beam from striking the sides of the tube.

c. To collect any secondary electrons emitted by the fluorescent screen.

d. To increase the brilliance of the trace by placing a negative voltage on the coating which accelerates the beam.

e. To provide shielding for the electron beam.



Alternate Drawing for Question 9

5. b . The term "persistence," when applied to cathode-ray tubes, means:

a. The tendency of the cathode to continue to emit electrons after filament power is removed.

b. The ability of the screen coating to continue to phosphoresce after the electron beam has moved on, or has been cut off.

c. The tendency of the aquadag coating to retain electrons which have been collected.

d. The tendency of the second anode to maintain a potential with respect to the third anode, causing defocusing.

6. What is the purpose of a paraphase amplifier?

To supply two signal voltages having equal amplitudes, but opposite polarity; these voltages are normally used as inputs to devices (amplifiers, deflection systems, etc.) requiring push-pull inputs.

7. What is the function of a cathode follower?

The cathode follower provides isolation and or impedance matching.

8. __c__. The cathode follower is a degenerative circuit in which feedback is obtained by means of:

a. Plate-to-grid interelectrode capacitance of the tube.

b. Grid-to-cathode tube capacitance.

c. The unby-passed cathode resistance.

d. The unby-passed plate load resistance.

9. Draw the complete circuit diagram of one type of saw-tooth generator.

10. Referring to the figure below, draw the waveforms that will appear across R and L.

11. __e__. Video amplifiers are necessary in radar circuits to pass the non-sinusoidal waveforms encountered because:

a. They increase the efficiency of the radar receiver.

b. Stage gain of this type of amplifier is higher than that of other amplifiers.

c. The use of the impedance coupling enables us to more easily integrate or differentiate the waveforms, as necessary for desired operation.

d. They are the best type of amplifier for passing the high frequencies used.

e. They have the flat response necessary to pass the many frequency components in square waves, peaked waves, etc., used in radar circuits.

DuMont type 208 Oscilloscope.

1. __d__. Moving the horizontal position control, R37, to its extreme down position:

a. Considerably reduces the length of the trace.

b. Causes the entire sweep on the scope face to move to the right.

c. Reduces the sync voltage.

d. Causes the entire sweep on the scope face to move to the left.

2. __c__. If C7 were to become shorted:

a. The only noticeable effect would be a reduction of the low-frequency response of the vertical amplifiers.

b. The only noticeable effect would be a reduction of the high-frequency response of the vertical amplifiers.

c. There would be no vertical deflection.

d. L1 would burn out.

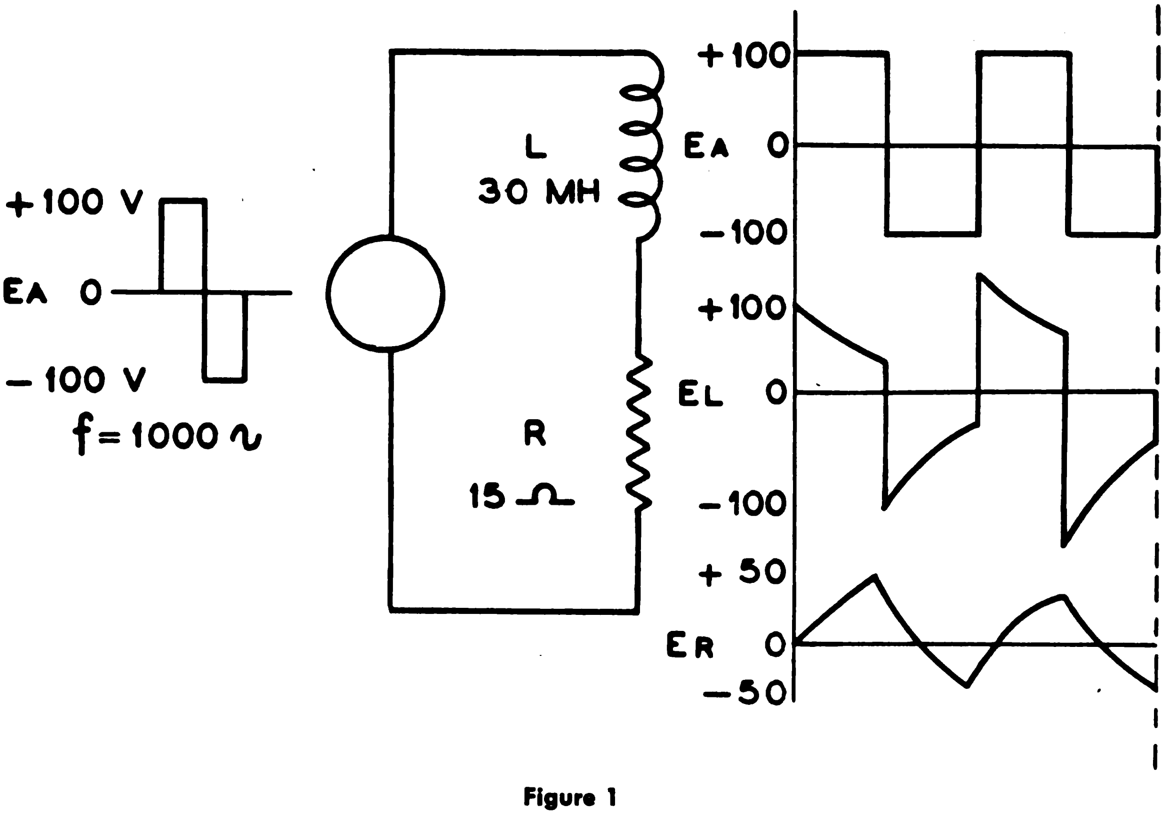


Figure 1

3. c . If the scope can be synchronized by means of an external signal, but not from an internal source, the following component is probably faulty:

a. V12.
b. C14 (to the left of V7).
c. S2 (to the left of V7).
d. V7.

4. d . When the scope is turned on, a spot appears on the screen, but there is neither vertical nor horizontal deflection. Which of the following components is probably defective?

a. V10.
b. V7.
c. V1.
d. V16.

5. a, c . The scope shows vertical deflection, but no horizontal sweep can be obtained in any position of the coarse frequency switch. Which components could be defective? (There may be more than one.)

a. V8.
b. R44 (plate of V11).
c. V10.
d. V11.
e. C16 (near V7).

6. b . The scope is operating properly except for a very objectionable retrace on the screen. Which of the following components is probably at fault?

a. V8.
b. Open C29 (near cathode-ray tube).
c. Open R49 (near cathode-ray tube).
d. V10.

7. b . The scope operates normally except that it is impossible to obtain any vertical deflection. Which of the following components is probably at fault?

a. R42 (near cathode of V10).
b. R21 (near cathode of V5).
c. L4 (near plate of V6).
d. C2 (near grid of V1).

8. a . Other indications are normal, but no horizontal trace appears. Switching to external sweep and placing a finger on one of the horizontal input terminals results in a horizontal line which can be varied in length by the horizontal gain control. Which of the following components is probably defective?

a. V7.
b. V8.
c. V9.
d. V10.

9. A new oscilloscope is unpacked, connected to the 115-volt power outlet, and turned on. After a reasonable warm-up time, no spot or horizontal trace can be obtained, and inspection shows the pilot lamp and tube filaments to be lighted somewhat dimly. What is the trouble?

S7 is in the 230 V position.

10. b . If L1 (near plate of V2) becomes shorted, what will be the effect?

a. The low-frequency response of the scope will decrease.
b. The high-frequency response of the scope will decrease.
c. No vertical deflection will be possible.
d. It will be impossible to synchronize the sweep internally.

11. c . If the sweep trace becomes very short, even with the horizontal gain control full up on, and the frequencies of the sweeps in all positions of the selector switch are much higher than normal, which of the following components is probably at fault?

a. C14 (open).
b. R34 (shorted).
c. C15 (shorted).
d. R33 (open).

12. c . If L2 were to become open, it would:

a. Cause excessive plate current to flow through V3, and probably damage the tube.
b. Have little noticeable effect, with some reduction in the high-frequency response of the vertical amplifiers.
c. Eliminate the vertical deflection.
d. Reduce the amplitude of the vertical deflection.

13. Briefly describe (in 25 words or less) the action of the beam on-off switch, S4, in blanking the cathode-ray tube when the switch is thrown to the "off" position.

This makes the cathode more positive than the top of R51 (Intensity), which, in itself, represents MORE than enough bias to cut off the beam.

14. a . Push-pull horizontal amplifiers are used:

a. To reduce astigmatism or defocusing of the trace.
b. To aid the positioning of the sweep.
c. To increase the brilliance of the trace.
d. To unblank the trace during the sweep periods.

15. Explain briefly (in 25 words or less) why provision is made for applying signals directly to the plates of the cathode-ray tube.

The amplifiers of the scope produce distortion. both at high frequencies and low frequencies. Applying a signal directly to the plates bypasses three amplifiers.

LESSON PLAN No. 31

SUBJECT

The electromagnetic cathode-ray tube.

OBJECTIVE

To discuss the theory of electromagnetic focusing and deflection.

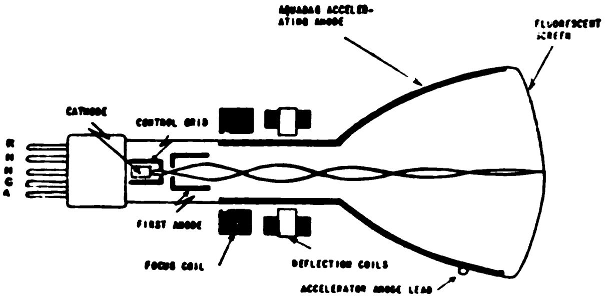


Figure 1

INTRODUCTION

The use of magnetic, instead of electrostatic, deflection and focusing makes it possible to obtain better definition, and is especially adapted to the generation of a radial sweep for certain types of radar indicators. It is important, therefore, that the student become familiar with the circuits used for magnetic deflection and focusing.

SUBJECT MATERIAL

1. Review the effects of a magnetic field upon an electron stream.

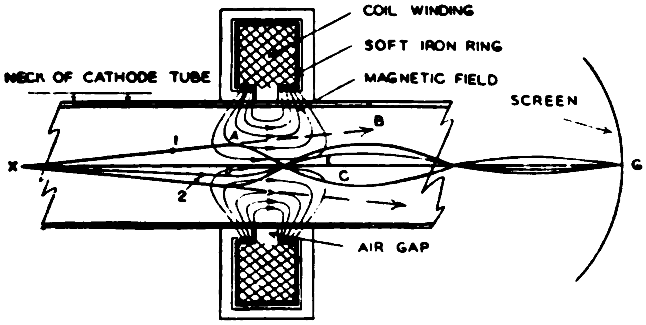


Figure 2

2. Discuss the construction of the electromagnetic cathode-ray tube. Note the similarities of, and differences between, the electromagnetic and electrostatic tubes, Figure 1.

3. Explain the operation of electromagnetic focusing, Figure 2.

4. Explain the operation of an electromagnetic deflection system, Figure 3.

   a. Show the distribution of the magnetic field required to produce deflection.

   b. Show how the deflection coils are situated around the tube.

   c. Explain the waveform requirements necessary to produce linear deflection.

5. Discuss oscillations occurring in deflection coils, and methods of suppressing them.

CONCLUSIONS

It is not to be concluded that the electromagnetic cathode-ray-tube is better than the electrostatic cathode-ray tube, or vice versa. It must be remembered that each has its own particular advantages. For any given application, therefore, a choice must be made between the two types, depending upon the characteristics desired for that particular application.

ORAL QUIZ

1. Give the advantages and disadvantages of the electromagnetic cathode-ray tube as compared with those of the electrostatic cathode-ray tube.

2. Why is a diode preferred to a resistor as a means of suppressing deflection-coil oscillations?

3. Explain the motion of electrons in a magnetic field.

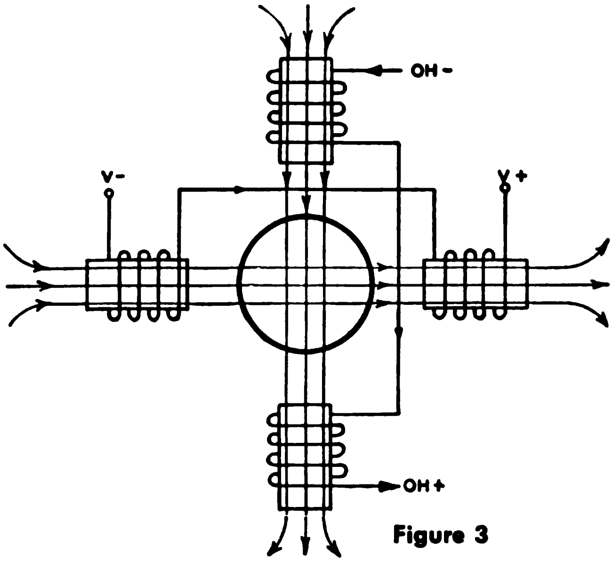


Figure 3

LESSON PLAN No. 32

SUBJECT

Security. (For current details, consult AFR 205-1.)

OBJECTIVE

To bring out important points of Security Regulations relevant to students of radar equipment.

INTRODUCTION

The importance of Security Regulations cannot be overstressed. "Useless" bits of information gathered by a clever espionage system can be tied together to form a complete and damaging story.

SUBJECT MATERIAL

Security means the safeguarding of military information.

1. Classified Matter.

Information or material in any form, or of any nature, which in the public interest must be safeguarded in the manner and to the extent required by its importance, is classified matter.

2. Document.

Any *recorded* information is considered a document (written, printed, drawn, recorded, photographed, or any other type of reproduction).

3. Material.

a. Material includes anything upon which information can be recorded.

b. Material includes any article, substance, or apparatus, whether *complete* or *in part,* in the process of research development and so forth, and anything associated therewith.

4. Technical Information.

Technical information includes instruction on maintenance, operation, performance, components, techniques, processes, and so forth.

5. Responsibility.

Safeguarding of classified military information is the responsibility of every individual (civilian or military).

6. Precautions Necessary for Safeguarding.

a. Discussions:

(1) No classified information may be discussed with persons not authorized to have knowledge thereof.

(2) When discussed with authorized persons, they must be informed that the information is classified.

b. Classified information may not be discussed over the telephone.

c. Personal correspondence will never include classified information.

7. No person is entitled to knowledge or possession of classified matter, solely by virtue of his grade or position.

8. Upon change of duty assignments, or separation from the military service, each individual will return TOP SECRET, SECRET, or CONFIDENTIAL documents.

9. Storage of SECRET or CONFIDENTIAL matter.

Such matter may be stored in steel file cabinets, secured by a steel bar and a three-position combination dial-type padlock, or a steel safe and so forth.

10. Loss or Subjection to Compromise.

Any person, civilian or military, must report loss or subjection to compromise of classified matter without delay to his immediate superior, who will take appropriate action.

11. CONFIDENTIAL matter includes such items as:

a. Military radio-frequency allocations.

b. Military call sign assignments. Information—quantity of specific items of equipment.

c. Technical documents and manuals used for training, maintenance, and inspection.

d. Information relating to the design and the development.

e. Communications intelligence information and security devices and material.

f. Technical information—such as research of processes of manufacture.

g. Photographs, negatives, photostats, diagrams, or models of CONFIDENTIAL matter.

h. Certain compilations of data or items, which individually may be unclassified, when assembled, may warrant a CONFIDENTIAL classification as defined above.

12. Handling a transmission of CONFIDENTIAL matter.

Nonregistered CONFIDENTIAL matter will be handled and transmitted in the same manner as prescribed for SECRET matter. This includes transmission within the Continental United States, as given below.

a. Transmission Within Continental United States.

(1) United States registered mail, including registered air mail.

(2) Protected commercial express.

(3) State Department diplomatic pouch, properly marked.

(4) Commanders or masters of vessels of United States registry.

(5) Military aircraft.

b. Transmission Outside Continental United States.

(1) United States Post Office registered mail through Army, Navy, or Air Force postal facilities.

(2) Specifically designated and cleared civilian employees.

(3) State Department diplomatic pouch, properly marked.

(4) Commanders or masters of vessels of United States registry.

(5) Military aircraft.

CONCLUSIONS

The above listed information is intended to direct the trainee's attention to the points which are pertinent to the field of electronics. Possession by the enemy of as little information as pulse rate and frequency of a particular equipment could render useless all your years of preparation.

ORAL QUIZ

1. Define the following:

a. Classified Matter.

b. Document.

c. Material.

d. Technical Information.

2. What type of information may not be discussed over the phone?

3. A few ways CONFIDENTIAL matter may be transmitted are:

a. Within Continental United States:

b. Outside Continental United States:

LESSON PLAN No. 33

SUBJECT

History of radar.

OBJECTIVE

To acquaint the student with the general history of the development and use of radar equipment.

INTRODUCTION

The history of the early development of radar is important to the understanding of modern radar equipment.

SUBJECT MATERIAL

1. Define the term "radar" as a contraction of the words radio detection and ranging.

2. Give a description of the capabilities of radar equipment, such as the ability to see or detect targets through darkness or overcast, etc.

3. Explain that radar works on the principle that radio energy transmitted from a given point may be reflected back to that point by some obstacle which lies in the path of this radiation.

4. Describe the early history of radar.

5. Describe the wartime radar development in the United States.

6. List and describe briefly the following wartime uses of radar.
   a. Search.
   b. Fire control or gun laying.
   c. Bombing.
   d. Navigation.

7. List some peace-time application of radar.
   a. Search and navigation.
   b. Ground controlled approach.

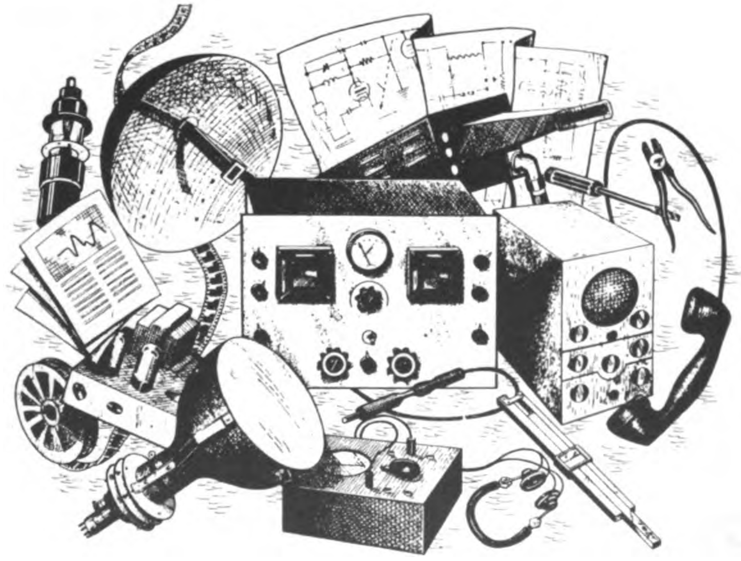
CONCLUSIONS

Since its inception, radar has become a valuable asset, proving itself first in war and then in peace. Mothered by the necessity for a weapon that would combat the ever-increasing menace of enemy aircraft, radar became of major importance during the war years. In peace time, its advantages in navigation and search are outstanding examples of its versatility.

ORAL QUIZ

1. Briefly sum up radar from its inception to the present day, covering the following points:
   a. Why it was needed.
   b. How it is used in war.
   c. How it is used in peace.

2. Explain the principles upon which radar is based.



History of Radar

LESSON PLAN No. 34

SUBJECT

Echo-ranging principles.

OBJECTIVE

To acquaint the student with the principles of echo-ranging.

INTRODUCTION

The ability of a radar system to accurately determine the presence of a target depends on the characteristics of the radio wave. Frequencies used in modern radar systems have many characteristics similar to light waves and, hence, may be compared to light waves in conducting discussions of echo-ranging.

SUBJECT MATERIAL

1. Explain to the class that, in pulsed radar systems, the transmitter is allowed to transmit for a short interval of time only. Between pulses, there is an interval known as the "resting time" of the system.

a. Explain that r-f energy leaves the antenna and travels through space with characteristics comparable to light.

b. R-F energy travels at 186,000 land miles per second, 162,000 nautical miles per second, or 328 yards per microsecond.

c. Explain that there are approximately 2000 yards to a nautical mile. This unit is being used almost universally as the standard range unit. (The nautical mile is to be used in future discussions in this course, unless specifically stated otherwise.)

2. Explain to the class that this energy which leaves the antenna travels in almost a straight line from the antenna unless it encounters some obstacle. When this occurs, a small fraction of the transmitted energy is returned from the object to the radar set. This return pulse is known as an echo.

a. Tell the class that this returned energy is very weak, often in the order of a fraction of a microvolt, even though the transmitted pulse which caused it may have had a peak power amplitude of a megawatt or more.

b. Set up an imaginary target one mile from the radar system, and show the class that the distance traveled by the r-f energy, to produce an echo, is exactly twice the distance from the radar to the target.

c. Explain to the class that when the r-f energy travels out from the radar unit one mile to a target and then returns to the equipment, we have established what is known as one "range mile." One land mile of radar range represents a time interval of 10.7 microseconds. One nautical mile of radar range represents a time interval of 12.2 microseconds.

3. Explain to the class the time relationship between the transmitted pulse and the echo return.

a. Set up a time base by which a saw-tooth voltage causes a trace to be formed on a cathode-ray-tube screen. Select a saw-tooth which has a time duration of 10 miles of range.

b. Explain to the class that the spot or trace on the cathode-ray tube moves from left to right, and that the trace starts at exactly the instant the transmitter fires.

c. Using a diagram, show how range is determined on a cathode-ray tube used as an indicating device of a radar system.

4. Describe to the class the methods used for determining the location of a target or object in azimuth, with respect to the radar set.

a. Explain, in detail, the single-lobe system. Show how beam width affects the angular accuracy, Figure 1.

b. Explain, briefly, the double-lobe system, Figure 2.

5. Discuss some methods that can be used to locate a target in elevation, Figures 3, 4, 5.

a. Explain the threshold-pickup method.

b. Explain the signal-comparison method.

c. Explain the tilted-antenna method.

CONCLUSIONS

The successful employment of pulse-modulated radar systems depends primarily on the ability to measure distance in terms of time. Radio-frequency energy, once it has been radiated into space, continues to travel with a constant velocity. When it strikes a reflecting object there is no loss in time, but merely a redirecting of the energy. Its velocity is that of light.

ORAL QUIZ

1. Explain the "resting time" in a pulsed radar system.

2. At what speed does r-f energy travel?

3. How do we determine one radar range mile?

4. How is azimuth determined in the location of a target or object?

5. How may elevation angles be determined?

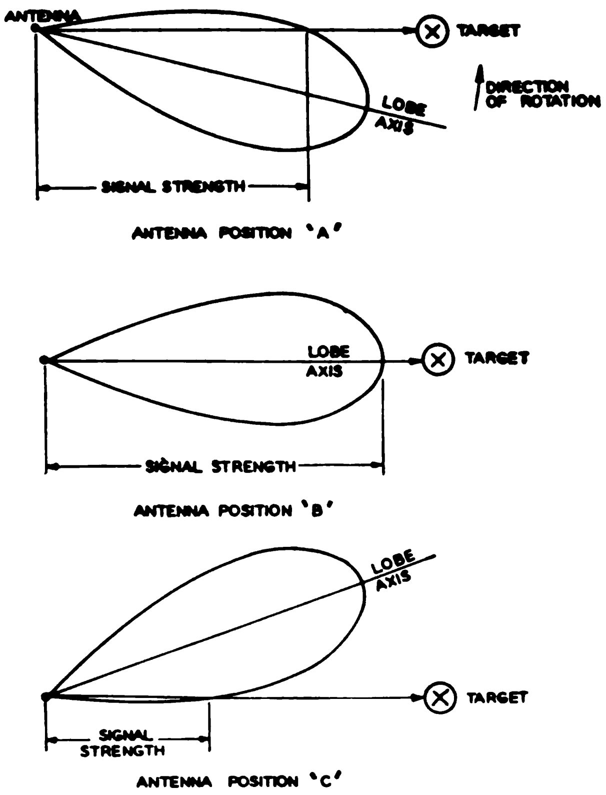


Figure 1

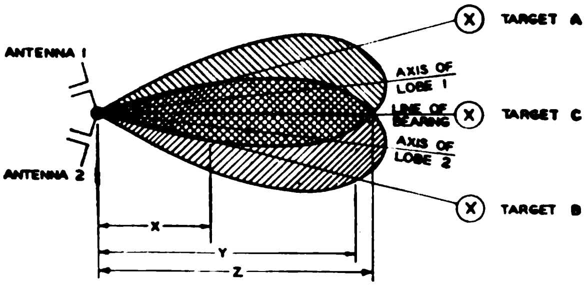


Figure 2

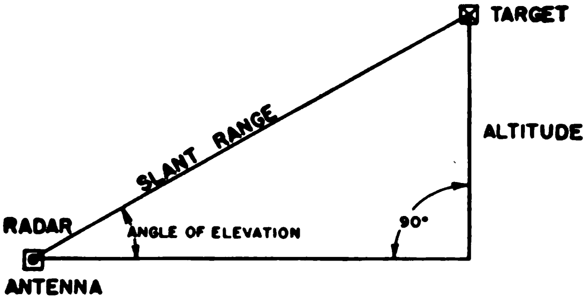


Figure 3

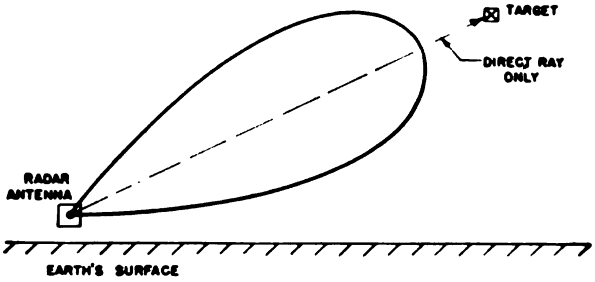


Figure 4

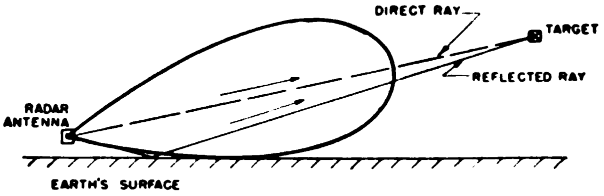


Figure 5

HOMEWORK SHEET No. 1

NOTE: This is the first of a series of HOMEWORK SHEETS which are intended for student use, to supplement the LESSON PLANS. These HOMEWORK SHEETS should be reproduced, and copies distributed to each student. The answers to the questions, of course, should not appear on the students' copies. It is suggested that all of the HOMEWORK SHEETS be reproduced (mimeographed, dittoed, etc.) at this time, so that they will be available whenever needed.

1. Name four wartime uses of radar. (Search, etc.)

a. Search.
b. Fire Control.
c. Identification—Friend or Foe.
d. Navigational aids.
e. Bombing.
f. Mapping.

2. Name three peacetime uses of radar.

a. Navigation.
b. Weather Observation.
c. Ground-Controlled Approach.
d. Search.

3. _c_. A microwave radar transmitter normally produces signals:

a. Continuously.
b. Half of the time.
c. In short pulses, with long resting periods between pulses.
d. Only when a traget has been located.

4. _c_. The actual speed of a radar wave is:

a. 186,000 statute miles per hour.
b. 162,000 nautical miles per hour.
c. 328 yards per microsecond.
d. 1 statute mile per 10.7 microseconds.
e. 1 nautical mile per 12.2 microseconds.

5. _c_. A range mile is defined as:

a. The same as a statute mile.
b. The same as a nautical mile.
c. Two actual miles — one mile out to the target, and one mile back.
d. One nautical mile — one-half mile out to the target, and one-half mile back.

6. _b_. A radar scope uses a saw-tooth horizontal sweep having a duration of 73.2 microseconds. It is capable of showing targets at a maximum distance of:

a. 1 mile.
b. 6 miles.
c. 12 miles.
d. 60 miles.
e. 100 miles.

7. _c_. When a single-lobe antenna is pointed directly at a target, the echo pip on the scope is:

a. Invisible. The proper direction is indicated by the disappearance of the echo from the scope.
b. Half of its maximum height.
c. As high as it is possible to make it.
d. At the left-hand side of the scope, next to the "main bang."
e. In the exact center of the scope screen.
f. At the extreme right-hand end of the sweep.

8. _b_. The double-lobe system of determining the azimuth of a target is superior to the single-lobe system because:

a. It is simpler.
b. It is much more accurate.
c. It provides a stand-by lobe in case of failure of either transmitter.
d. It can be used for elevation determination as well as for determining azimuth, whereas the single-lobe system can be used only for finding azimuth.

9. Name three methods used in the determination of the elevation of a target.

a. Threshold pickup.
b. Signal comparison.
c. Tilted antenna.

10. _b_. It is necessary to use a sweep that traces across the scope every few microseconds because:

a. It is desired to keep a constant check upon the movements of the target.
b. The scope will not display a bright image

unless its phosphor is excited every few microseconds by a beam of electrons.

c. There is no way of keeping the sweep from starting every time the transmitter emits a pulse of energy.

d. There is no way of keeping the transmitter from emitting a pulse of energy every time the sweep starts.

11. _a_. Azimuth is usually expressed as:

a. The angle between a line drawn from the observer to the target and a line drawn from the observer to true north.

b. The angle between a line drawn from the observer to the target and a line drawn from the observer to the true heading of his airplane.

c. The angle between a line drawn from the observer to the target and a line drawn from the target to true north.

d. The angle between a line drawn from the observer to the target and a line drawn from the target to magnetic north.

12. _a_. A single-lobe directional antenna produces a maximum echo from a distant target when the center line of the lobe:

a. Passes directly through the target.

b. Is aimed at an angle of 90 degrees to the line joining the observer and the target.

c. Is aimed so as to pass above the target at an angle of 33-1/3 degrees.

d. Is aimed directly away from the target.

13. _d_. The threshold-pickup method of determining elevation:

a. Does not involve the use of a chart.

b. Can be relied upon for accuracy to within 500 feet of the correct elevation.

c. Uses two separate antennas.

d. Is very inaccurate.

14. _d_. The signal-comparison method of determining elevation:

a. Uses a single antenna.

b. Is very inaccurate.

c. Uses an antenna that can be moved in a vertical plane.

d. Uses two antennas.

15. _a, b_. The tilted-antenna method of determining elevation:

(Choose all correct answers.)

a. Uses a single antenna.

b. Avoids the influence of ground reflections.

c. Makes use of a chart.

d. Requires the comparison of two received signals.

LESSON PLAN No. 35

SUBJECT

Typical Radar Systems.

OBJECTIVE

To acquaint the student with the general form and content of typical radar systems through the use of block diagrams.

MATERIAL REQUIRED

REFERENCE SHEETS, pages 108-109 (1 each per student).

SUBJECT MATERIAL

1. Radar systems may be classified fundamentally into a number of groups.
   a. Emission.
      (1) Pulsed (most important to date).
      (2) FM.
      (3) CW (Doppler).
   b. Frequency.
      (1) Microwave.
      (2) Long wave.
   c. Timing.
      (1) Self synchronized.
      (2) Externally synchronized.

2. In order to function as a radar system, an equipment must contain at least the following units: a transmitter, a receiver, an antenna, and an indicator. The necessity for a power supply is obvious, but it need not be indicated in the discussion at this point.

a. Draw and explain a block diagram containing these essential units of a radar system.

b. Explain the fact that it is not practical to use two antennas; therefore, an arrangement was developed by which the antenna is connected to the transmitter when it is operating, and then switched to the receiver during the remainder of the time. Tell the class that this switching device is called the transmit-receive (T-R) switch.

3. Explain to the class the necessity for a timing device which causes the transmitter to become operative at the same time the sweep starts on the scope.

a. Draw and explain the basic pulsed radar system block diagram.

b. Draw and describe the basic pulsed radar system shown on REFERENCE SHEET 2-1. Describe the modulator as the unit which determines the duration of time that the transmitter is operative. Distribute REFERENCE SHEET 2-1 to the class.

c. Explain to the class that, with a pulsed system, it is possible to determine the range and/or bearing of a target.

d. Draw and briefly describe the "A," "B," "C," and "PPI" indicator presentations used with the pulsed system. Refer to REFERENCE SHEET 2-2, which is to be distributed to the class.

4. Draw and describe the operation of the continuous wave doppler radar system shown in the block diagram on REFERENCE SHEET 2-1.

a. Explain the fact that this system will indicate relative radical motion of targets, and might serve to give early warning only. The figure will show azimuth location of the object by virtue of antenna directivity, but no range.

b. Tell the class that this system is not widely used.

5. Draw and describe the operation of the FM radar system shown in the block diagram on REFERENCE SHEET 2-1.

a. This system is capable of determining range and/or azimuth information.

b. This system is not too widely used, although it does find application as an elevation-determining system.

CONCLUSIONS

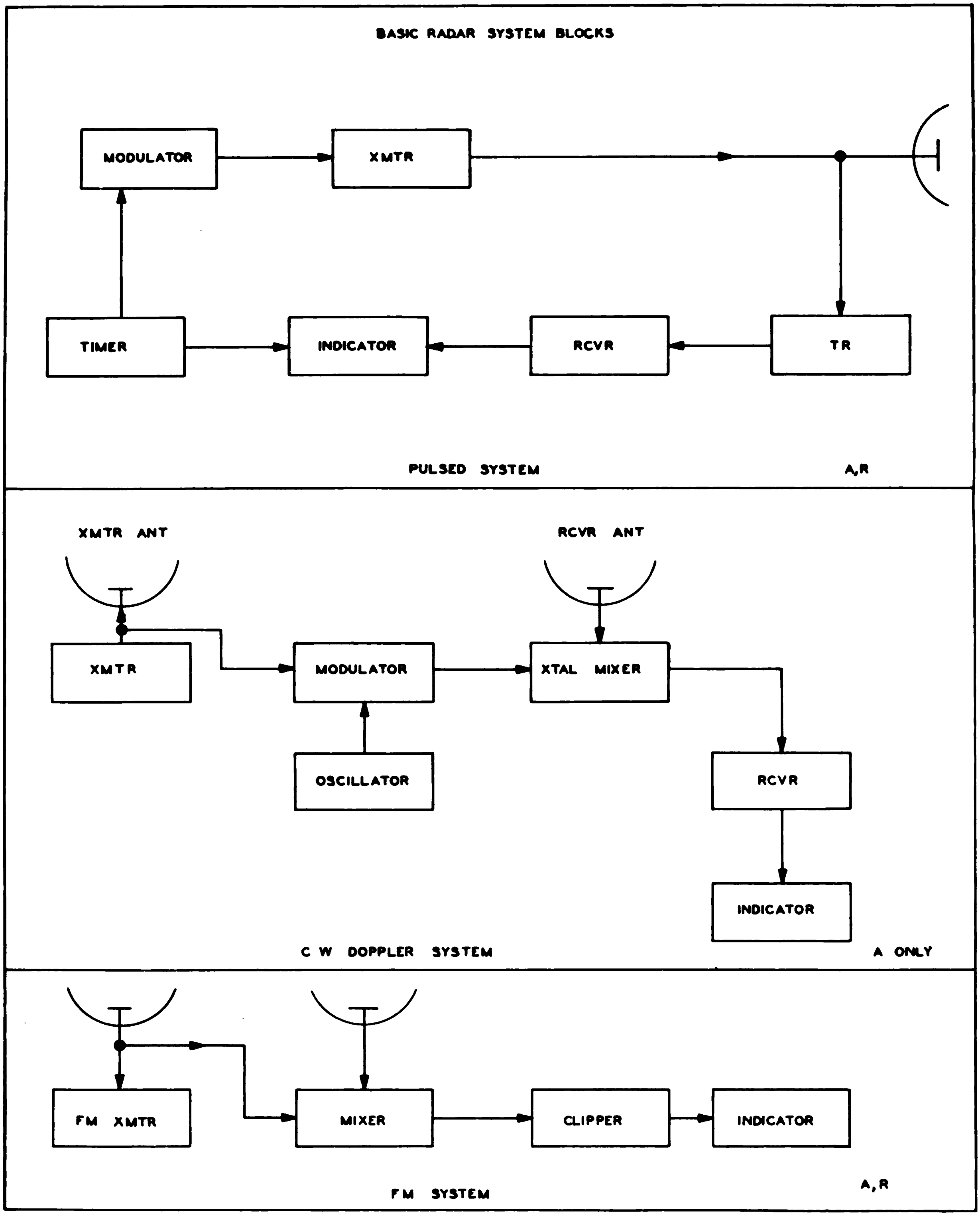
Radar systems may be classified according to characteristics such as emission, frequency, and timing; however, they all, fundamentally, consist of the following units: a transmitter, a receiver, an antenna, an indicator, and a power supply. The most important system to date is the pulsed radar system.

ORAL QUIZ

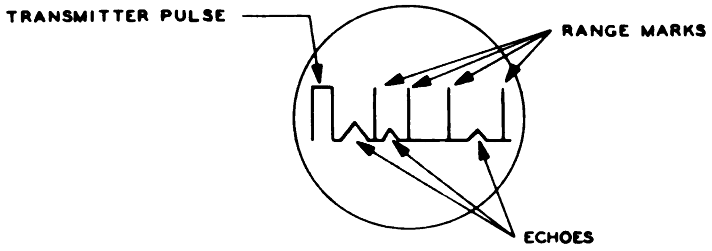
1. What are the essential fundamental units of a practical radar set?

2. Why is it not practical to use two antennas?

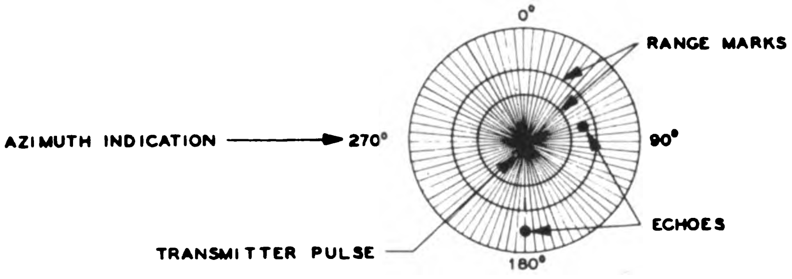
3. What is the continuous-wave doppler system and why is it not widely used?



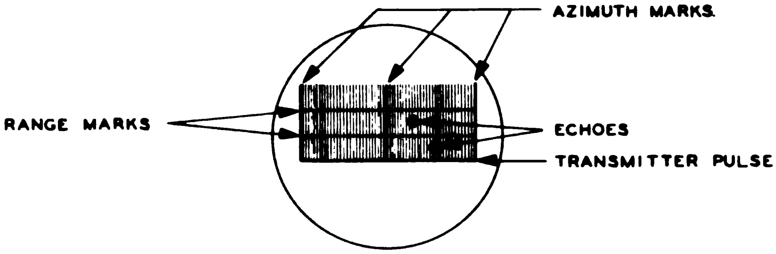
Reference Sheet 2-1



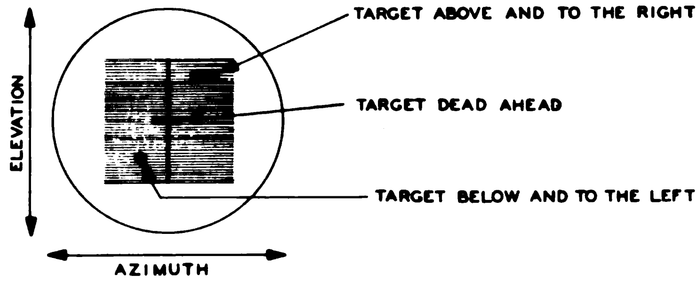
"A" PRESENTATION



PPI PRESENTATION



"B" PRESENTATION



"C" PRESENTATION

Reference Sheet 2-2

HOMEWORK SHEET No. 2

1. _a_. Pulsed radar systems are more important, at present, than other types.
   - a. True.
   - b. False.

2. _b_. FM radar systems are used to detect moving objects while blanking out all stationary objects.
   - a. True.
   - b. False.

3. _b_. CW (Doppler) radar systems are used frequently in radar altimeters.
   - a. True.
   - b. False.

4. _a_. Microwave radar systems have largely supplanted long-wave radar systems in modern equipment.
   - a. True.
   - b. False.

5. Draw from memory a block diagram of the pulsed radar system.

6. Draw from memory a block diagram of the CW Doppler radar system.

7. Draw from memory a block diagram of the FM radar system.

8. _a_. The Doppler system:
   - a. Is capable of indicating azimuth only by reason of a directive antenna.
   - b. Will show range, but not azimuth.
   - c. Is widely used in radar altimeters.
   - d. Will show elevation, but not range or azimuth.

9. _d_. The ordinary FM radar system:
   - a. Is capable of determining range, but not azimuth.
   - b. Is capable of determining azimuth, but not range.
   - c. Is capable of displaying azimuth, range, and elevation on one scope.
   - d. Is used in radar altimeters.

10. Draw from memory a scope face carrying an "A" presentation of transmitter pulse, echoes, and range marks.

11. Draw from memory a scope face carrying a "PPI" presentation of transmitter pulse, echoes, and range marks.

12. Draw from memory a scope face carrying a "B" presentation of transmitter pulse, echoes, range marks, and azimuth marks.

13. Draw from memory a block diagram of a fundamental radar system. Include the waveforms produced by each block.

REFERENCE SHEET 2-3.

Obtain a clear idea of the meaning of the following terms:

a. Carrier frequency.
b. Pulse width.
c. Pulse repetition frequency.
d. Peak power.
e. Duty cycle.
f. Beam width.

Be able to explain the functions of the following:

a. The timer.
b. The transmitter.
c. The antenna.
d. The receiver.
e. The indicator.
f. The various power supplies shown in the block diagram of Figure 5, Losson Plan No. 37.

LESSON PLAN No. 36

SUBJECT

Radar system constants.

OBJECTIVE

To familiarize the student with the general electrical characteristics of radar systems.

MATERIAL REQUIRED

REFERENCE SHEET 2-3 (1 per student).

INTRODUCTION

The system constants of a radar set are determined by the range, accuracy, and physical size of the equipment.

SUBJECT MATERIAL

1. Explain what is meant by the carrier frequency of a radar system.

   a. Explain what factor influences the lowest frequency that can be used practically for a radar system.

   b. Explain what factors influence the highest frequency that can be used practically for a radar system, i.e., serious attenuation of the energy above 10,000 megacycles, and high-power considerations.

   c. List some typical carrier frequencies.

2. Explain what is meant by the pulse width of a radar system.

   a. Show how the pulse width affects the minimum range of a radar system.

   b. List some typical pulse widths.

3. Explain what is meant by the pulse repetition frequency of a radar system.

   a. Show how the p. r. f. affects the maximum range of a radar system.

   b. Explain that the higher the p. r. f., the better the definition of the equipment.

   c. Explain what factors influence the lowest and highest p. r. f. that can be used with a radar system.

   d. Explain resting time.

   e. List some typical p. r. f.'s.

4. Discuss the term "peak power" and its effect upon range. List some typical peak powers.

5. Explain what is meant by the duty cycle of a radar system.

Show the relationship between peak power and average power, and between pulse width and p. r. f.

6. Explain what is meant by the beam width of the equipment.

   a. Show how the beam width is measured at the half-power points.

   b. Explain how the beam width affects the definition of the equipment and the angular accuracy obtainable.

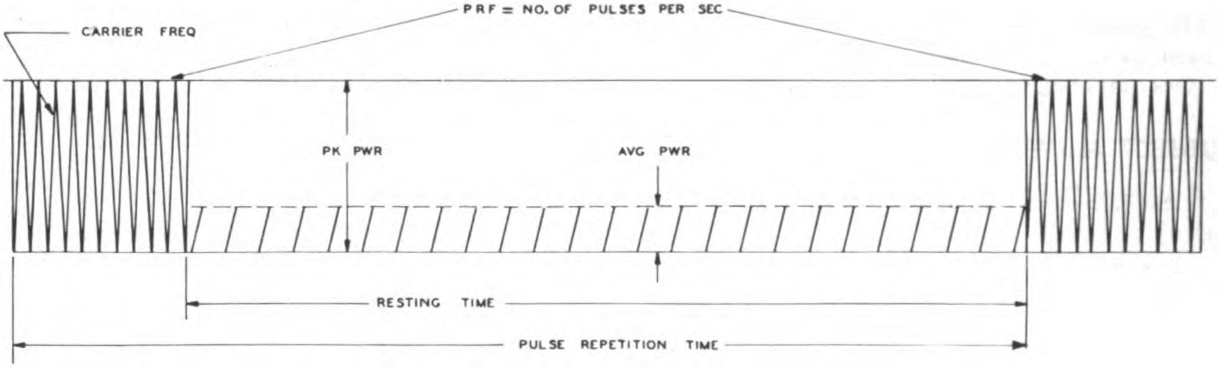
CONCLUSIONS

Any radar system has certain electrical constants associated with it. The choice of these constants for a particular system is determined by its tactical use, the accuracy required, the range to be covered, the practical physical size, and the manner of generating and receiving the signal.

ORAL QUIZ

1. What factors influence the lowest and highest frequencies that can be used practically in a radar set?
2. What does the pulse width of a radar system affect?
3. What is the effect of peak power upon range?

RADAR SYSTEM CONSTANTS



① $\text{PRF} = \frac{1}{\text{PULSE REP TIME}}$

② $\text{AVG PWR} = \frac{\text{PULSE WIDTH} \times \text{PEAK POWER}}{\text{PULSE REP TIME}}$

③ $\text{DUTY CYCLE} = \frac{\text{PULSE WIDTH}}{\text{PULSE REP TIME}}$

④ $\text{DUTY CYCLE} = \frac{\text{AVERAGE POWER}}{\text{PEAK POWER}}$

Reference Sheet 2-3

HOMEWORK SHEET No. 3

1. a . The carrier frequency of a radar transmitter is:

a. The frequency at which the transmitter oscillates.

b. The rate at which pulses of energy are emitted by the transmitter.

c. The frequency to which the klystron of the radar receiver is tuned.

d. The frequency to which the input circuit of the receiver is tuned. (This is different from the transmitter frequency).

2. b . The lowest carrier frequency commonly used in modern radar equipment is:

a. 50 megacycles.
b. 100 megacycles.
c. 1000 megacycles.
d. 10,000 megacycles.

3. d, e . Factors limiting the highest carrier frequency that it is practical to use are: (choose all correct answers.)

a. The frequency at which the klystron will oscillate.

b. The frequency at which a magnetron can be made to oscillate.

c. The size of the antenna necessary to produce a sharp beam.

d. The attenuation of power at high frequencies, by atmospheric conditions, etc.

e. The difficulty of obtaining sufficient amplification from the i-f amplifier of the receiver.

4. c . The principal factor limiting the lowest carrier frequency that it is practical to use is:

a. The frequency range over which the klystron will oscillate.

b. The frequency range over which the magnetron will oscillate.

c. The size of the antenna necessary to produce a sharp beam.

d. The attenuation of power at low frequencies, due to ground reflections.

e. The excessive amounts of power required by low-frequency radar systems.

5. b . The pulse width of a radar transmitter is:

a. The width (in microseconds) of one individual cycle of the transmitter's oscillating output.

b. The time which elapses between the instant when the transmitter begins to oscillate and the instant when it stops oscillating.

c. The time which elapses between the instant when the transmitter stops oscillating, and the instant when it resumes oscillation.

d. The time which elapses between the instant when the transmitter stops oscillating and the instant when the first echo appears on the scope screen.

6. c . If the pulse width of a radar transmitter is increased:

a. The maximum range of the radar is decreased.

b. The average power developed by the transmitter is decreased.

c. The minimum range of the radar is increased.

d. The antenna becomes detuned and the equipment ceases to operate.

7. b . A certain radar has a pulse width of 0.8 microsecond, a carrier frequency of 3000 megacycles, and a pulse repetition frequency of 2000 p.p.s. The minimum range of this equipment is:

a. Approximately 10 miles.
b. Approximately .065 mile.
c. 262.4 yards.
d. Limited only by the curvature of the earth.

8. a, b, c, d . Average power, in radar equipments, is: (Choose all correct answers.)

a. The reading of an r-f wattmeter connected to the output of the transmitter.

b. The total power delivered by the system, averaged over a long period — for example, 1 second.

c. Very low, compared with the peak power.

d. Calculated by the formula:

$$\text{Average power} = \text{Peak power} \left(\frac{\text{Pulse width}}{\text{Pulse repetition time}} \right)$$

9. c . A radar transmitter emits 0.5-microsecond pulses at a peak power of 100 kilowatts. The pulse repetition frequency is 1500 p.p.s. The average power output is:

a. .75 milliwatts.
b. 7.5 milliwatts.
c. 75 watts.
d. 750 watts.

10. d . The duty cycle of a radar transmitter is:

a. The time during which it is actually transmitting energy.

b. The time required for an echo to return from the most distant target it is desired to observe.

c. The ratio of the pulse width to the pulse repetition frequency.

d. The ratio of the average power to the peak power.

11. d . A radar transmitter has a duty cycle of .001, an average power of 30 watts, a pulse repetition frequency of 500 p.p.s., and a carrier frequency of 2500 megacycles. What is the peak power developed?

a. 17 watts.
b. 17 kilowatts.
c. 1.7 megawatts.
d. 30 kilowatts.

12. b . The pulse repetition frequency of a radar system is:

a. The time required for one complete cycle (pulse plus resting period).

b. The number of transmitter pulses occurring per second.

c. The highest frequency that can be used with a cathode-ray tube of a given persistence.

d. The lowest frequency that can be used with a cathode-ray tube of a given persistence.

13. a,b . Increasing the pulse repetition frequency will: (Choose all correct answers.)

a. Allow observation of targets that lie at greater distances from the observer.

b. Improve the definition of the system.

c. Make it necessary to use a larger antenna system.

d. None of the above is correct.

14. The lowest pulse-repetition frequency is determined by:

a. The persistence of the indicator screen.
b. The speed of rotation of the antenna.

15. b . Resting time is defined as:

a. The time interval during which the scope sweep is cut off, preventing the appearance of spurious targets.

b. The interval of time between transmitter pulses, during which the transmitter is emitting no power.

c. The time interval between the end of a transmitter pulse and the instant when the first echo arrives.

d. The time interval between the instant when the last target arrives and the instant when the transmitter begins its next pulse.

16. a . In an "A" scope presentation, the horizontal axis represents:

a. Range.
b. Elevation.
c. Azimuth.
d. Velocity of the target.

17. c . In a "B" scope presentation, the horizontal axis represents:

a. Range.
b. Elevation.
c. Azimuth.
d. Velocity of the target.

18. d . In a PPI presentation, the horizontal axis represents:

a. Range.
b. Elevation.
c. Azimuth.
d. None of the above is correct. There is no horizontal axis.

19. d . In an "A" scope presentation, the vertical axis represents:

a. Range.
b. Elevation.
c. Azimuth.
d. None of the above is correct.

20. a . In a "B" scope presentation, the vertical axis represents:

a. Range.
b. Elevation.
c. Azimuth.
d. Any two of these quantities may be selected for presentation on the vertical axis.

21. a . In an "A" scope presentation, range marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, some distance above the horizontal axis.

d. Concentric rings.

22. b . In a "B" scope presentation, range marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, some distance above the horizontal axis.

d. Concentric rings.

23. d. In a "PPI" presentation, range marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, some distance above the horizontal axis.

d. Concentric rings.

24. d. In an "A" scope presentation, azimuth marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, some distance above the horizontal axis.

d. None of the above is correct. There are no azimuth marks on an "A" scope presentation.

25. a. In a "B" scope presentation, azimuth marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, some distance above the horizontal axis.

d. None of the above is correct. There are no azimuth marks on a "B" scope presentation.

26. d. In a "PPI" presentation, azimuth marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, some distance above the horizontal axis.

d. None of the above is correct. There are no azimuth marks on a "PPI" presentation.

27. a. In an "A" scope presentation, targets appear on the screen as:

a. Small pips, spaced along the horizontal axis.

b. Small pips, spaced along the vertical axis.

c. Small pips whose bases rest some distance above the horizontal axis.

d. Bright spots appearing anywhere on the screen except in the exact center.

28. d. In a "B" scope presentation, targets appear on the screen as:

a. Small pips, spaced along the horizontal axis.

b. Small pips, spaced along the vertical axis.

c. Small pips whose bases rest some distance above the horizontal axis.

d. Bright spots appearing anywhere on the screen except on the horizontal axis.

29. d. In a "PPI" presentation, targets appear on the screen as:

a. Small pips, spaced along the horizontal axis.

b. Small pips, spaced along the vertical axis.

c. Small pips whose bases rest some distance above the horizontal axis.

d. Bright spots appearing anywhere on the screen except in the exact center.

30. What is the function of a timer?

The function of the timer is to insure that all circuits connected with the radar system operate in a definite time relationship with each other, and that the interval between pulses is of the proper length.

31. What is the difference between timing by a separate unit and timing within the transmitter?

The pulse repetition frequency can be determined by an oscillator of any stable type. The output is then applied to the necessary pulse-shaping circuits, to produce the required timing pulse. This is timing by a separate unit.

The transmitter, with its associated circuits, may establish its own pulse width and pulse repetition frequency, and provide the synchronizing pulse for the other components in the system. This is timing within the transmitter.

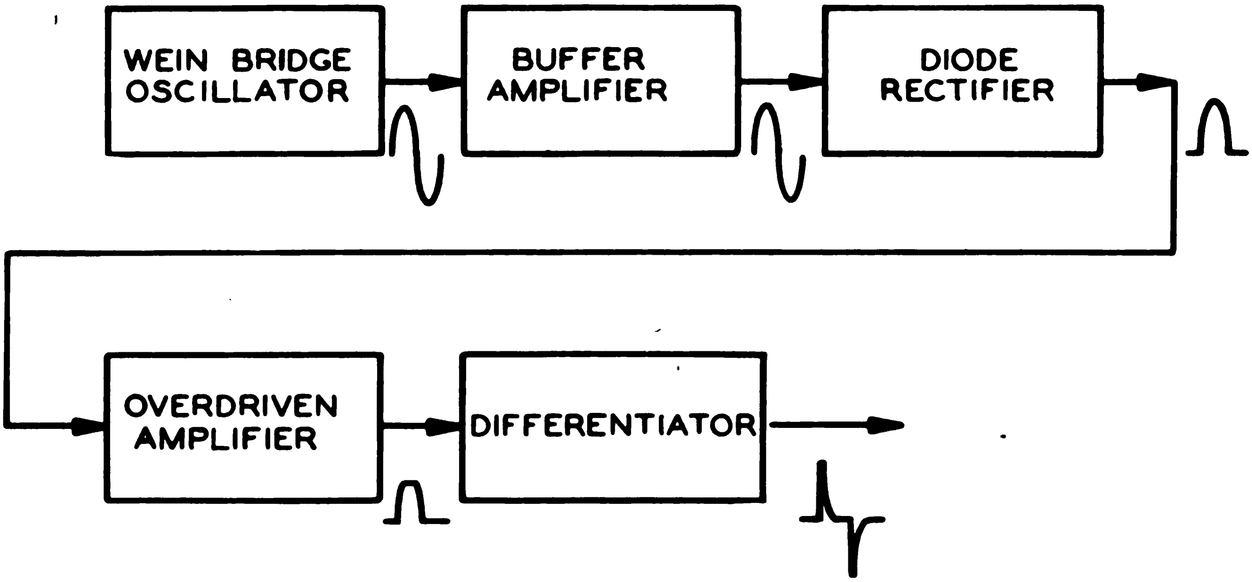
32. Draw from memory the block diagram of a timer.

33. What is the function of the radar transmitter?

The function of the transmitter in a radar system is to generate the r-f energy in the form of short, powerful pulses.

34. What is the difference between the self-pulsed system of radar transmission and the externally pulsed system?

In the self-pulsed radar transmitter, the func-



Suggested Drawing (Question 32)

tion of transmitting and timing are carried out by one component.

In the externally pulsed type of radar transmitter, the function of the r-f oscillator is to generate powerful pulses of r-f energy at regular intervals. The oscillator requires power from an accurately timed, high-amplitude, rectangular pulsing circuit.

35. Draw from memory the block diagram of a self-pulsing oscillator, functioning as a transmitter and timer.

36. What is the function of the antenna system in a radar installation?

The function of the antenna system is to take the energy from the transmitter, radiate it in a directional beam, pick up the returning echo, and pass it to the receiver, with a minimum of losses.

37. Why is a two-antenna system impractical for most radar use?

To prevent the receiving antenna (and hence, the receiver) from picking up the powerful signal from the transmitting antenna, it must be properly shielded. If it were not, damage to the receiver would result.

38. What piece of equipment must be added to the installation if the two-antenna system is replaced by a single-antenna system?

A T-R box switching arrangement, to keep the receiver inoperative during the transmission of pulses.

39. Radar antennas must have very narrow beam widths in order to provide:

a. Definition.
b. Range.
c. Better accuracy for azimuth for elevation.

40. Draw a simple diagram and explain how you would determine the width of a radar beam.

Beam width is the angle produced by two lines having a common point of origin at the antenna and intersecting a third line, perpendicular to the axis of the beam, at the half-power points.

41. What is the function of the radar receiver?

The radar receiver amplifies the weak r-f pulses returned by the target, and reproduces them as video pulses, to be applied to the indicator.

42. Draw from memory the block diagram of a radar receiver.

43. What is the function of the radar indicator?

The indicator produces a visual indication of the echo pulses in a manner which furnishes the required information.

44. Draw from memory the block diagram of a basic indicator chain. Explain its operation.

The sync pulse from the timer operates the sweep which puts the trace on the cathode-ray tube. It also triggers the gate which times the sweep and transmitted pulse, for proper relationship on the indicator. The video signal from the receiver is applied directly to the indicator, to present the echo information.

45. Explain the functions of the various radar power supplies shown in the block diagram of Figure 5, Lesson Plan No. 37.

Filament transformer supplies filament voltages.

Full-wave rectifier and voltage regulator supply B+ to receiver and indicator.

Voltage doubler supplies B+ to transmitter.

High-frequency power supply supplies cathode-ray-tube indicator voltage.

Half-wave rectifier supplies cathode-ray-tube monitoring voltage.

Half-wave rectifier and gas-tube voltage regulator supply local-oscillator repeller voltage.

D-C generator supplies the relays, blower motors, antenna control, and motors.

46. c . In a "C" scope presentation, the horizontal axis represents:

a. Range.

b. Elevation.

c. Azimuth.

d. None of the above is correct. There is no horizontal axis.

47. b . In a "C" scope presentation, the vertical axis represents:

a. Range.

b. Elevation.

c. Azimuth.

d. None of the above is correct. There is no vertical axis.

48. e . In a "C" scope presentation, range marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Bright stationary spots, located anywhere except on the horizontal axis.

d. Concentric rings.

e. None of the above is correct. There are no range marks on a "C" scope presentation.

49. a . In a "C" scope presentation, azimuth marks appear on the screen as:

a. Vertical lines, spaced along the horizontal axis.

b. Horizontal lines, spaced along the vertical axis.

c. Concentric rings.

d. None of the above is correct. There are no azimuth marks on a "C" scope presentation.

50. d . In a "C" scope presentation, targets appear on the screen as:

a. Small pips, spaced along the horizontal axis.

b. Small pips, spaced along the vertical axis.

c. Small pips whose bases rest some distance above the horizontal axis.

d. Bright spots.

LESSON PLAN No. 37

SUBJECT

General analysis of radar system chains.

OBJECTIVE

To teach the student the general characteristics of all principal sections of a pulsed radar system.

INTRODUCTION

In order to learn the operation of a pulsed radar system, it is important that the student be familiar with the functions of all major units of the system.

SUBJECT MATERIAL

1. Refer the class to the pulsed radar system block diagram shown in REFERENCE SHEET 2-1, (Page 108).

2. Describe the function of the timer.

Describe timing by a separate unit, and timing within the transmitter. Draw and explain the block diagrams of a sine-wave oscillator timing circuit, a multivibrator timing circuit, and a blocking oscillator timing circuit, Figure 1.

3. Explain the function of the transmitter.

Describe the self-pulsed system and the externally pulsed system, listing the differences between them. Show a block diagram of an oscillator functioning as a transmitter and timer, and another of an externally pulsed transmitter, Figure 2.

4. Explain the function of the antenna.

a. Show that a two-antenna system is impractical; therefore, a system employing a single antenna and a T-R unit is most widely used.

b. Explain that radar antennas usually are very directional, having very narrow beam widths.

5. Explain the function of the radar receiver.

Draw and explain the radar receiver block diagram showing its components and typical physical arrangement, Figure 3.

6. Explain the function of the radar indicator.

a. Describe, in detail, type "A," "B," "C" and "PPI" presentations. See Reference Sheet 2-2, (Page 109).

b. Explain the major components of an indicator chain, Figure 4.

7. Explain the necessity for, and the functions of, various power supplies, such as a filament transformer, a full-wave rectifier, a voltage doubler, a high-frequency power supply, a half-wave rectifier, and regulators, Figure 5.

CONCLUSIONS

In order to more fully understand the general characteristics of all principal sections of a pulsed radar system, the student should be thoroughly acquainted with the functions of the timer, the transmitter, the antenna, the radar indicator, and the various power supplies.

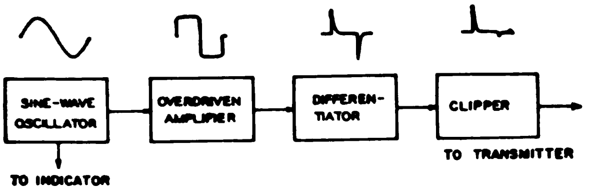
ORAL QUIZ

1. Compare timing by a separate unit and timing within the transmitter.

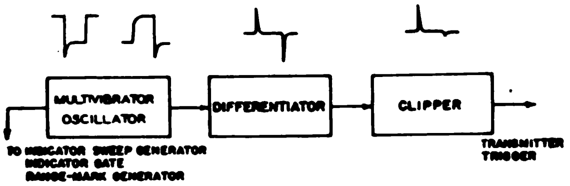
2. Why is a two-antenna system impractical?

3. Name and explain various radar indicator presentations.

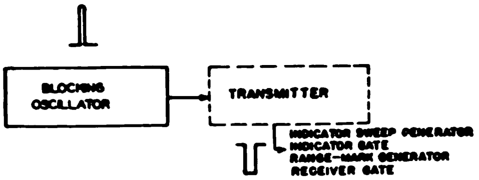
4. Name various radar power supplies.



① SINE-WAVE-OSCILLATOR TIMING CIRCUIT



② MULTIVIBRATOR TIMING CIRCUIT



③ BLOCKING-OSCILLATOR TIMING CIRCUIT SHOWING INDIRECT SYNCHRONIZATION

Figure 1

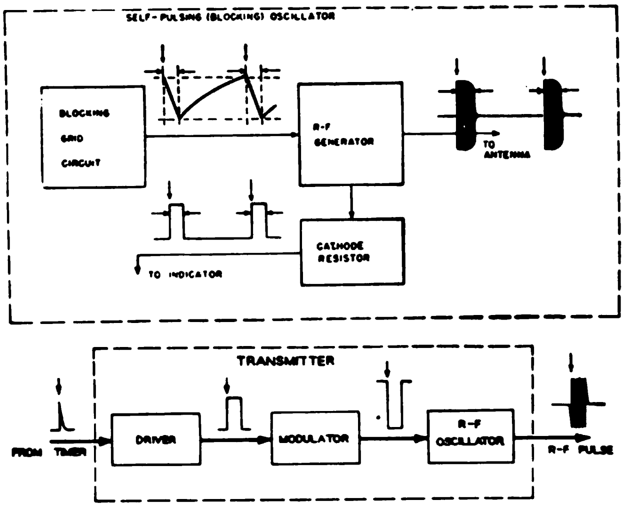


Figure 2

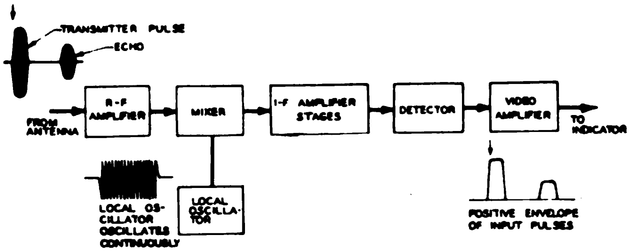


Figure 3

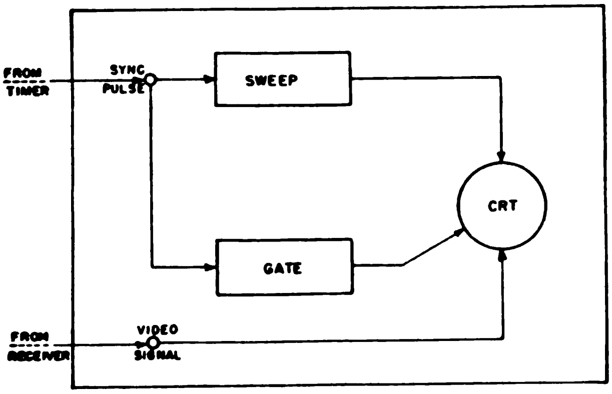


Figure 4

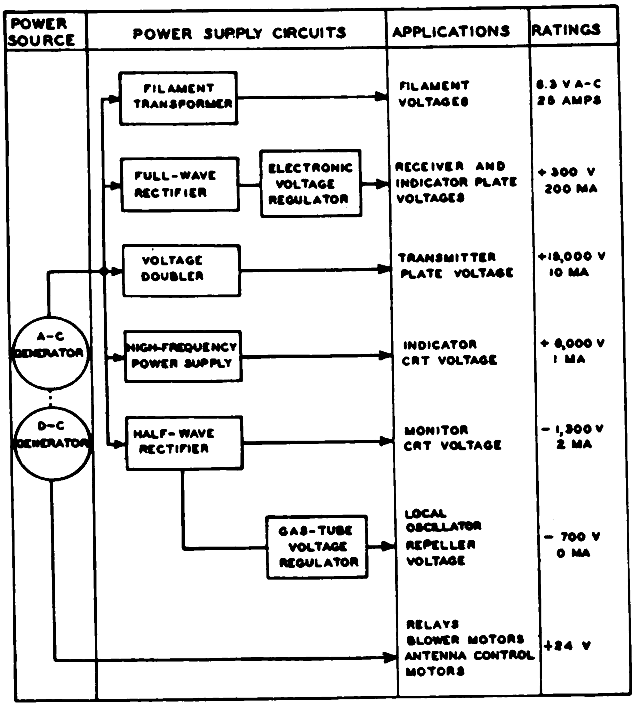


Figure 5

HOMEWORK SHEET No. 4

1. b . In a self-synchronized radar system, timing pulses are produced by:

a. A separate unit, known as the timer chain.

b. The transmitter circuit itself, which acts as a master oscillator.

c. Neither of the above is correct. The source of timing pulses has nothing to do with determining whether a system is self-synchronized or externally synchronized.

d. Neither of the above is correct. A self-synchronized radar system does not use timer pulses at all.

2. a . In an externally synchronized radar system, timing pulses are produced by:

a. A separate unit, known as the timer.

b. The transmitter itself, which acts as a master oscillator.

c. Neither of the above is correct. The source of timing pulses has nothing to do with determining whether a system is self-synchronized or externally synchronized.

d. Neither of the above is correct. An externally synchronized radar system does not use timer pulses at all.

3. a, f, i, k . The timer may be called upon to supply any of the following timing pulses: (Choose all correct answers.)

a. A pulse to trigger the transmitter chain.

b. A pulse of r-f energy to be fed to the antenna.

c. A pulse of r-f energy to be fed to the receiver.

d. An r-f echo pulse.

e. A pulse of energy to actuate the T-R box.

f. A rectangular pulse of voltage to be applied to the receiver plates and/or screens.

g. A video pulse to be fed to the grid of the cathode-ray tube.

h. An antenna-positioning pulse.

i. A pulse to start the indicator sweep generator.

j. A pulse to blank out the indicator during the forward sweep of the saw-tooth voltage.

k. A pulse to block the grid of the marker generator during the forward sweep of the saw-tooth voltage.

4. In the space provided below, draw synchrogram of timer pulses.

5. e . Some equipments do not use a receiver gate pulse because:

a. The use of a gate pulse makes it impossible to observe targets at close range.

b. The use of a gate pulse interferes with the normal operation of the T-R box.

c. The use of a gate pulse may cause the life of the crystal mixer to be shortened.

d. The normal blocking of the receiver by the main bang makes additional gating unnecessary.

e. None of the above is correct.

6. a, d . The sweep in a magnetic deflection scope may be caused to start at the precise instant at which the main bang starts by: (Choose all correct answers.)

a. Delaying the transmitter trigger.

b. Delaying the sweep-generator trigger.

c. Making the transmitter trigger and the sweep-generator trigger start at the same instant.

d. Use of a trapezoidal sweep.

7. d . The indicator gate is used to:

a. Make the receiver inoperative during the emission of the transmitter pulse.

b. Make the transmitter inoperative during the entire resting period.

c. Make the indicator inoperative during the entire resting period.

d. Make the indicator operative during the forward stroke of the sweep, and inoperative during the rest of the cycle.

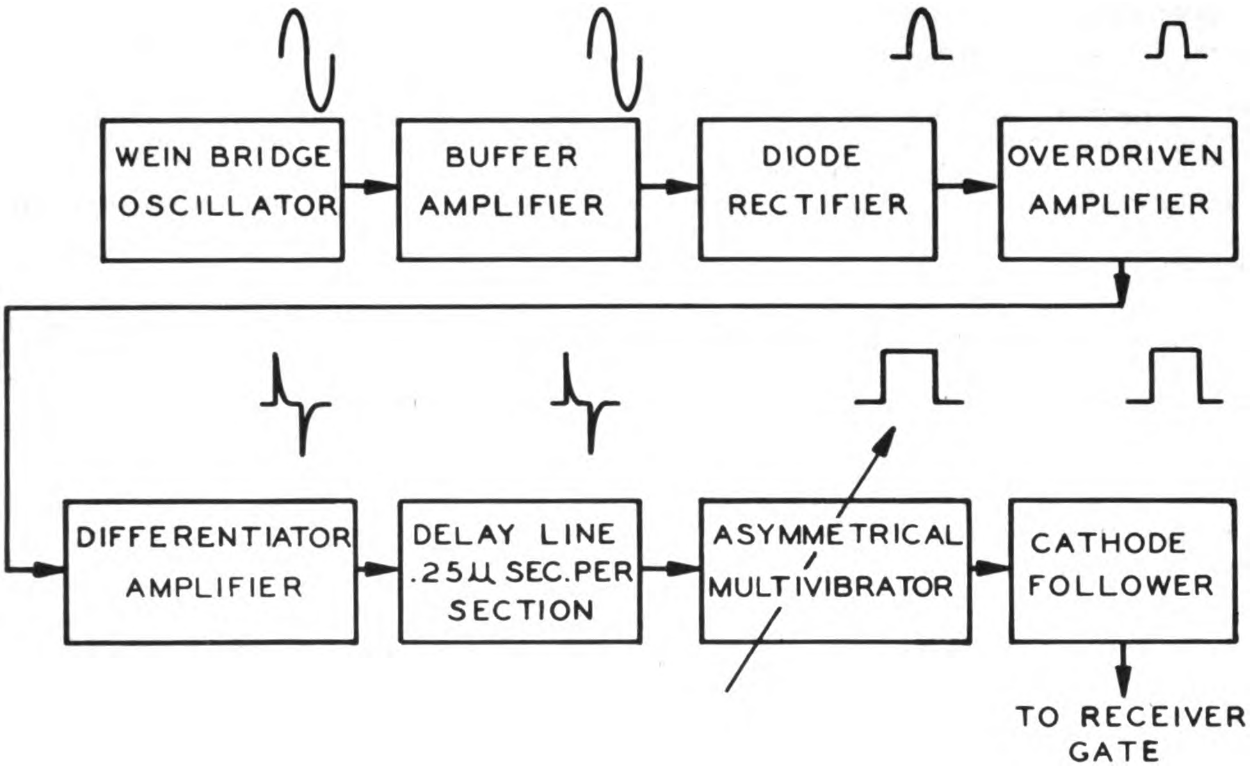
8. a . If an indicator gate were not used:

a. A confusing back trace would appear on the scope.

b. "Second-time-around" echoes might appear on the scope.

c. The trace on a magnetic scope would not start for an instant after the indicator trigger pulse was applied, thus introducing an error into the calibration.

d. An excessive number of range marks might appear on the scope, unless the marker gate were also made inoperative.



Suggested Drawing for Question 23

9. b . The indicator gate shown in 3 of figure 1 on page 119 is suitable for application to the_________of the scope tube:

a. Cathode.
b. Control grid.
c. First anode.
d. Second anode.
e. Vertical-deflection plates.
f. Horizontal-deflection plates.
g. Aquadag.

10. c . If used with a vacuum-tube saw-tooth generator, the sweep trigger shown would have to be converted into:

a. A sharp negative pulse.

b. A positive-going rectangular pulse, whose width corresponds to the duration of the sweep.

c. A negative-going pulse, whose width corresponds to the duration of the sweep.

d. A trapezoidal wave.

11. What circuit, used during your laboratory course, would produce marker pulses like those shown on page 126, when triggered by a marker gate similar to the one shown on the same page?

Self-excited oscillator.

12. Name three types of circuits that must be included in a timer.

a. Those capable of providing a pulse repetition frequency.

b. Those capable of forming or shaping waveforms.

c. Those designed to isolate drivers from loads.

13. b . Self-synchronized radar systems are:

a. More complicated than externally synchronized systems.

b. Suitable for search-type radar.

c. Suitable for gun-laying radar.

d. More susceptible to jamming.

14. Which of your laboratory chassis uses a circuit of the type suitable for use in a self-synchronized radar transmitter?

Self-pulsing blocking oscillator.

15. d . A rotary spark gap is sometimes used in a radar system to:

a. Generate a pulse of r-f energy.
b. Establish a rigidly accurate timing pulse.
c. Form a rectangular modulator pulse of definite width.
d. Establish a moderately steady timing rate for the system.

16. A rotary spark gap, as used in radar systems, produces rectangular pulses for the following purposes:

a. To trigger the r-f pulse transformer.
b. To go to the indicator.

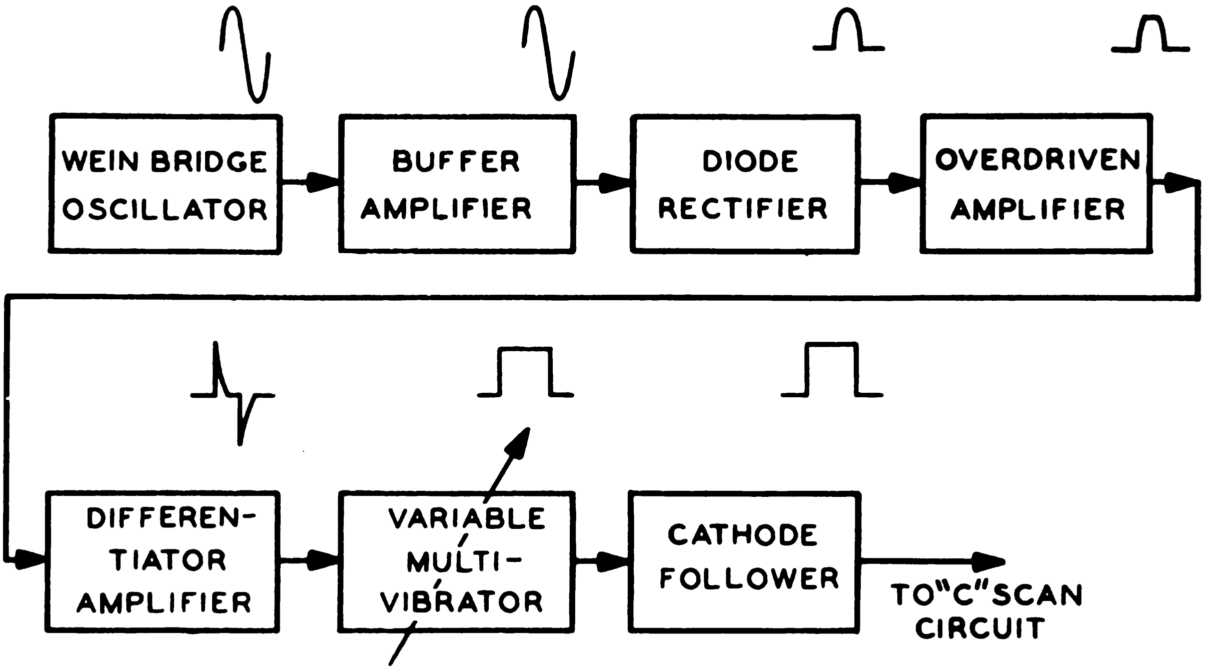
17. Draw a schematic diagram of a rotary-spark-gap circuit capable of producing 1.5-microsecond timer pulses having a p.r.f. of 800 p.p.s.

18. b . A sine-wave oscillator is sometimes used in radar timers to:

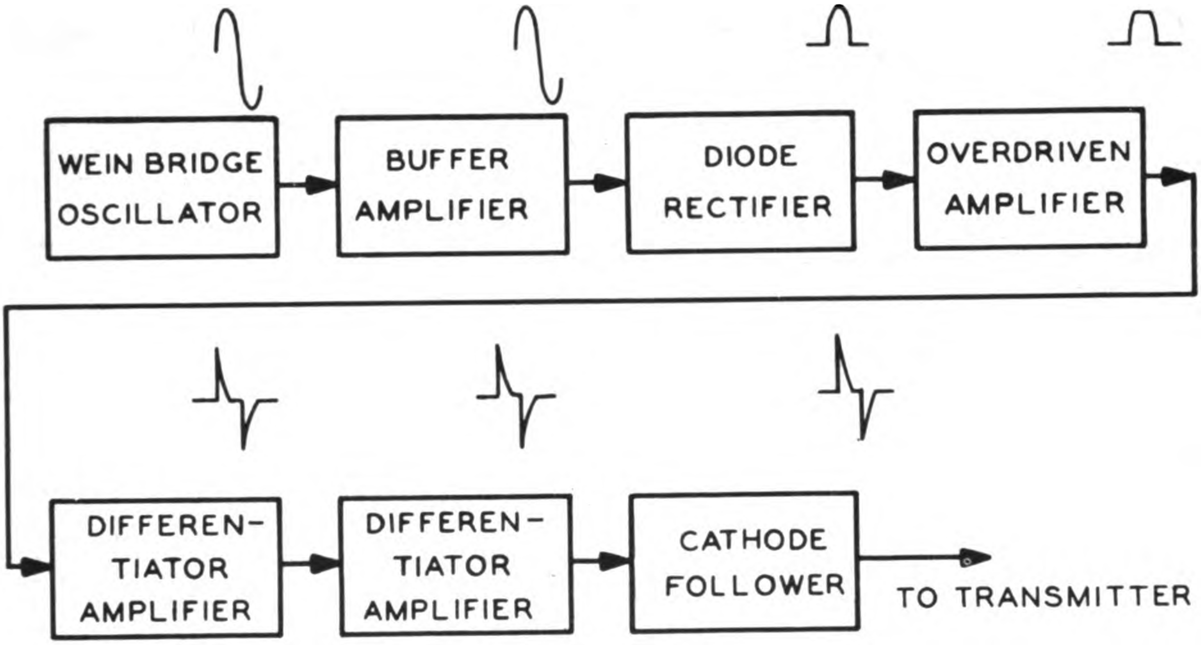
a. A-f modulate the transmitter pulse.
b. Establish rigid timing of the system.
c. Set up r-f oscillations that are amplified by the transmitter tube and radiated by the antenna.
d. Provide a simple, light-weight circuit for airborne use.

19. a, f . The following sine-wave oscillator circuits are stable enough for use in timer circuits: (Choose all correct answers.)

a. Wein bridge.
b. Tickler feedback.
c. Hartley.
d. Colpitts.
e. Tuned-grid, tuned-plate.
f. Phase shift.



Suggested Drawing for Question 24



Suggested Drawing for Question 25

20. Number the following stages in the order in which they would ordinarily be used for a timer chain.

2 Buffer amplifier.

5 Differentiator amplifier.

3 Diode rectifier (limiter).

1 Wein-bridge oscillator.

4 Overdriven amplifier.

21. Draw a block diagram showing the timer chain mentioned in question 20. Show the output waveform of each stage.

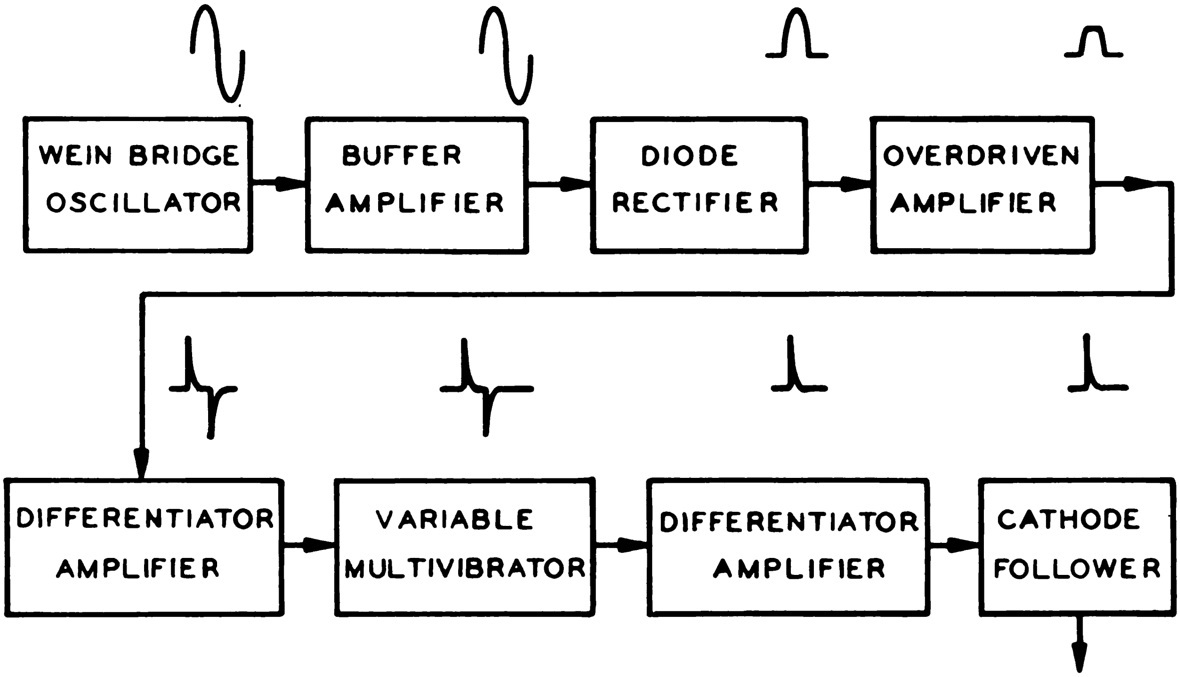
22. Draw a block diagram of the circuits used to trigger a B scan. Show the output waveform.

23. Draw a block diagram of the circuits used to gate a receiver in the system described. Show all output waveforms.

24. Draw a block diagram of the circuits used to gate the "C" scan indicator in the system mentioned above. Show all waveforms produced.

25. Draw a block diagram of the circuits used to produce the transmitter trigger in the system mentioned above. Show all waveforms involved.

26. Draw a block diagram of the circuits used to produce the "B" scan marker pips in the system mentioned above. Show all waveforms.



Suggested Drawing for Question 26

LESSON PLAN No. 38

SUBJECT

Timer systems.

OBJECTIVE

To teach the student the characteristics of various timer systems used in pulsed radar systems, and of the vacuum-tube stages used in these timers.

INTRODUCTION

The timer of a pulsed radar system may be properly called the heart of the system. It produces the signals which correctly synchronize the operation of all components of a radar equipment.

SUBJECT MATERIAL

1. Review, briefly, the function of the timer.

a. Draw a block diagram of the timer and the circuits it triggers. Briefly explain the general use of the timer outputs, Figure 1.

b. Draw a synchrogram of the waveforms at the various outputs. Explain that the timer controls the start of all these waveforms, Figure 2.

2. Briefly explain the types of self-synchronized radar systems.

a. Explain self-synchronization of a radar system with a self-blocking r-f oscillator as a transmitter. Show how the timing pulse for the system is taken from the circuit, Figure 3.

b. Explain self-synchronization with a rotary spark gap as a modulator in a pulsed radar system. Draw and explain a block diagram of a typical rotary-spark-gap modulator which provides the necessary timing pulses for the system, Fig. 4. Do not explain the theory of the pulse-shaping line; it will be covered in a later discussion.

3. Explain to the class that the self-synchronizing, or internally synchronizing timers are not widely used in airborne equipments, but are used quite commonly with early warning and ground-controlled intercept radars.

4. Explain to the class the fact that various timer chains have been developed to handle the different requirements of radar systems, and that these timers supply various types of triggers and gates, and utilize various master circuits to initiate complexity; i.e., multivibrator timer, blocking-oscillator timer, and sine-wave timer. An example of indirect timing will be discussed in conjunction with the blocking-oscillator timer.

5. Draw and explain the block diagram of a typical multivibrator timer chain, Figure 5.

Explain that the purpose of delaying the transmitter pulse and gates for the markers and unblanking is to give the sweeps time to start before the transmitter fires.

6. Draw the schematic diagrams and explain the operation of the following circuits of the multivibrator timer.

a. A symmetrical multivibrator as a master oscillator, Figure 6.

b. Transmitter trigger section of multivibrator timer, Figure 7.

c. The "PPI" gate section of the multivibrator timer, Figure 8.

d. The "A" scope gate and IFF trigger section of the multivibrator timer, Figure 9.

e. While explaining the operation of these circuits, show the development of all waveforms. Explain the use to which all these waveforms are put.

7. Present to the class the block diagram and schematic analysis of the blocking-oscillator timers. Explain the circuit theory of these timers, using the circuit diagrams, Figure 10.

Explain both the direct and indirect timer chains, following the same general form as that given in paragraphs 5 and 6 above.

8. Present to the class the block diagram and schematic analysis of the sine-wave timer. Explain the circuit operation of this timer, using the circuit diagrams.

CONCLUSIONS

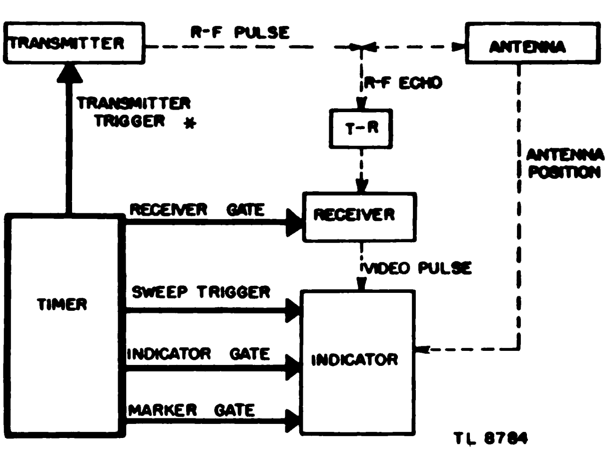
Homework Sheet No. 5, Question 1.

Circuits which control and synchronize the operation of the various components of radar equipments are known as timers. The timing circuits are either assembled into a unit which constitutes a separate component of the equipment, or, as in the usual case, they are contained within a number of units of the equipment, such as the indicator, the receiver, and the control circuits.

For purposes of study, timers have been divided into two general types. One is the self-synchronized type, in which the timing function is performed within the transmitter circuits. The other is the externally synchronized type, in which a master oscillator in the timer establishes the repetition rate and supplies trigger voltages for controlling the entire system.

ORAL QUIZ

1. Name three or four important uses of the timer in radar equipment.
2. How is a self-blocking r-f oscillator used as a transmitter in self-synchronized radar systems?
3. Internally synchronizing timers are not widely used in airborne systems. Why?



* ESTABLISHES THE TIME REFERENCE FOR THE SYSTEM

Figure 1

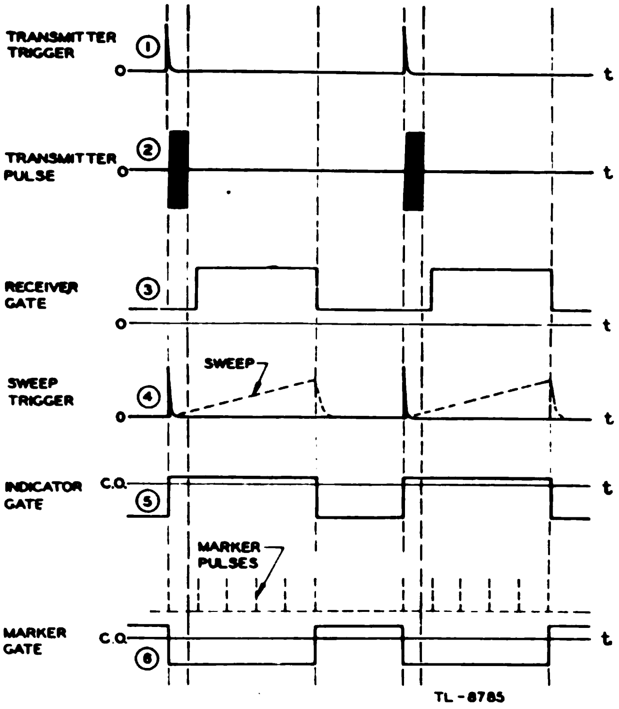


Figure 2

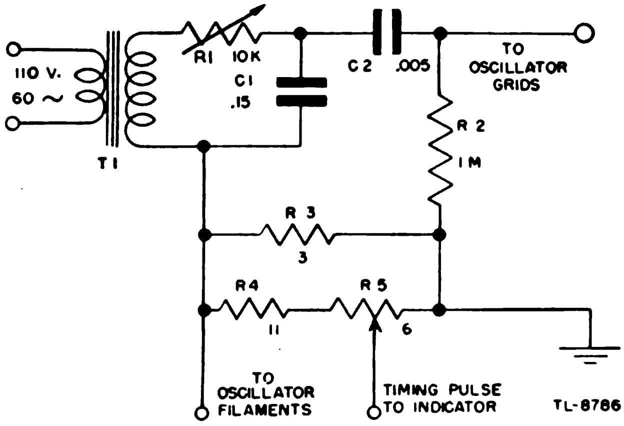


Figure 3

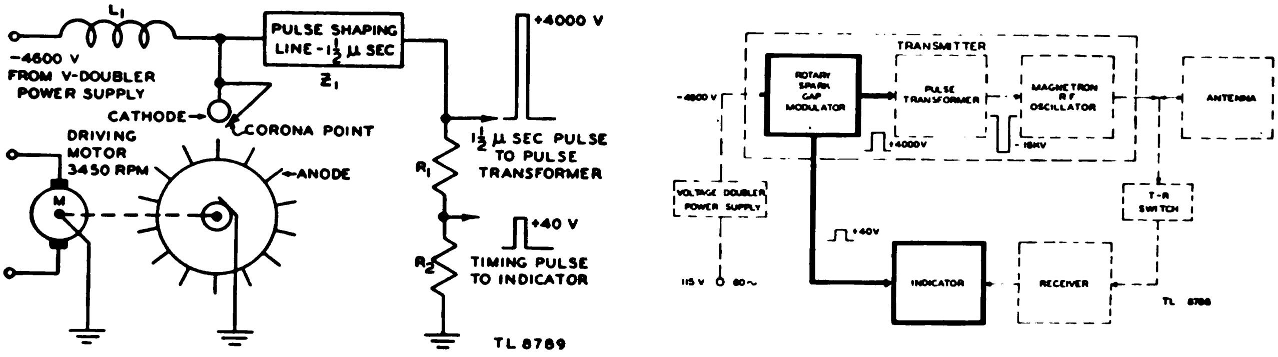


Figure 4

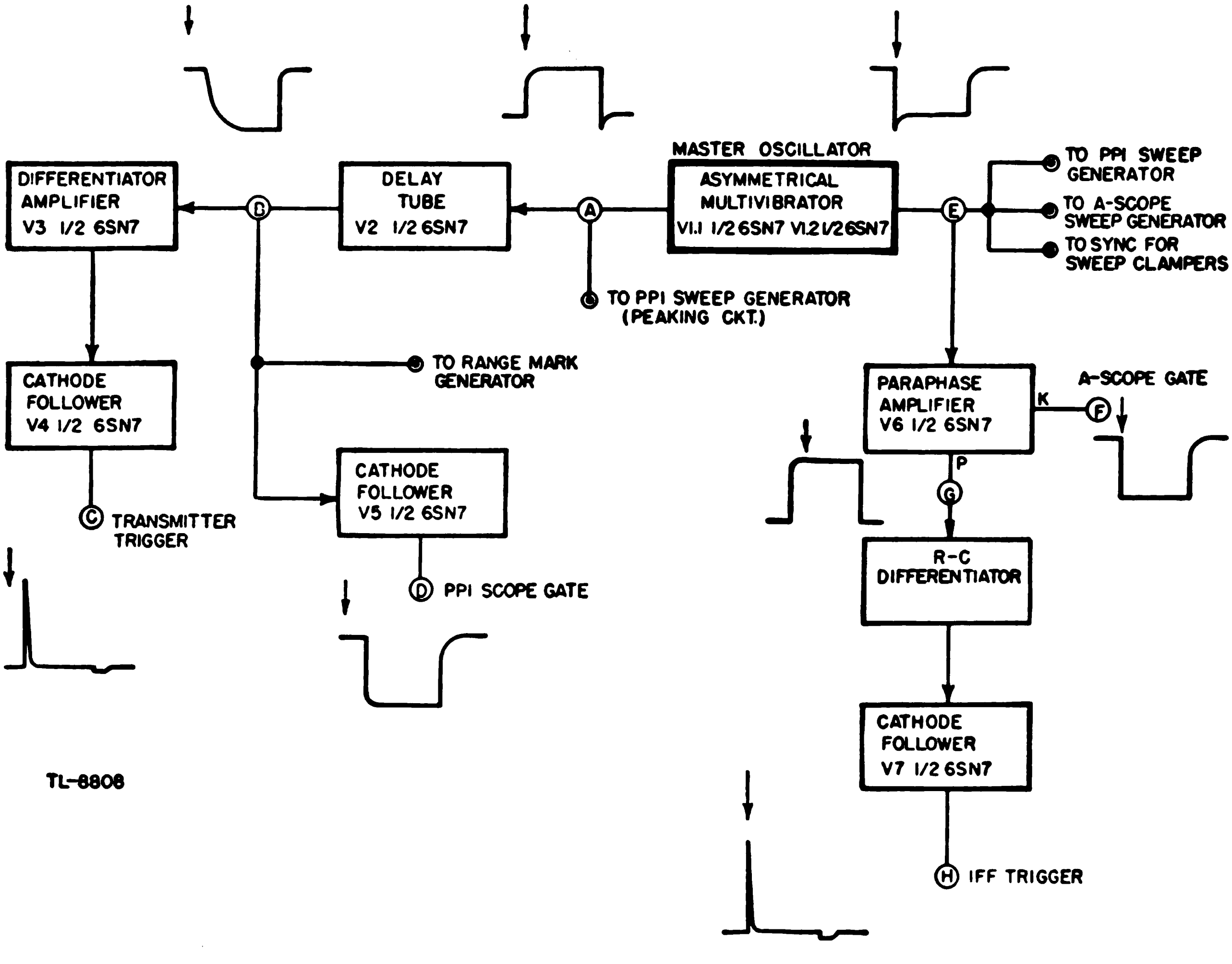


Figure 5

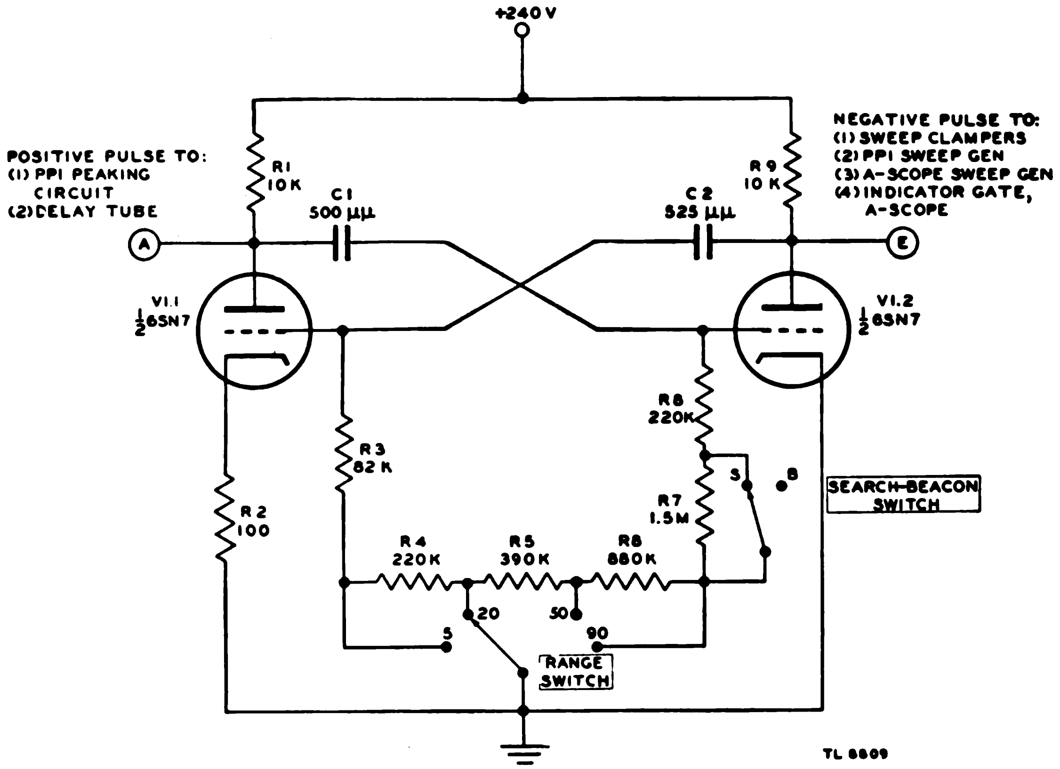


Figure 6

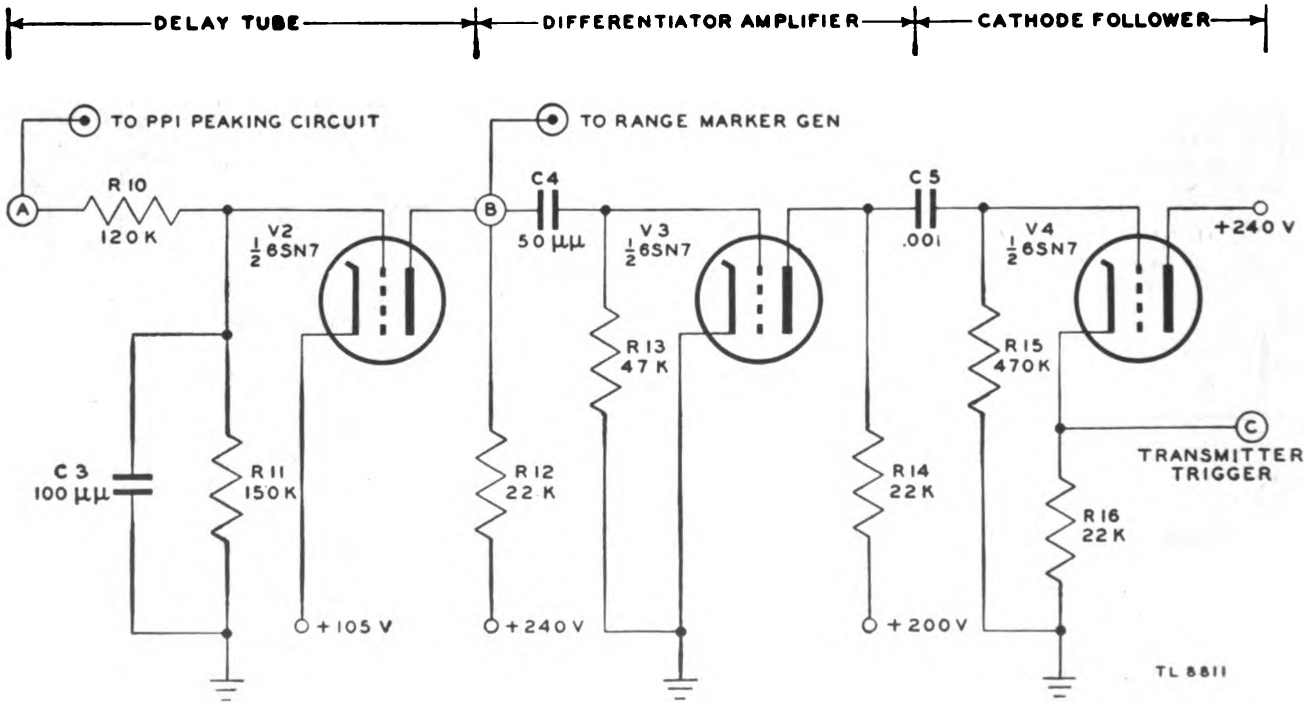


Figure 7

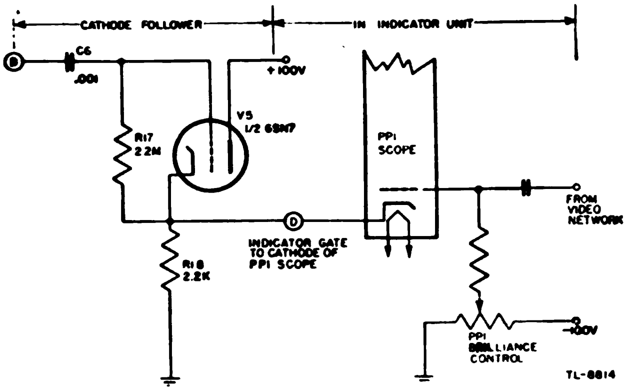


Figure 8

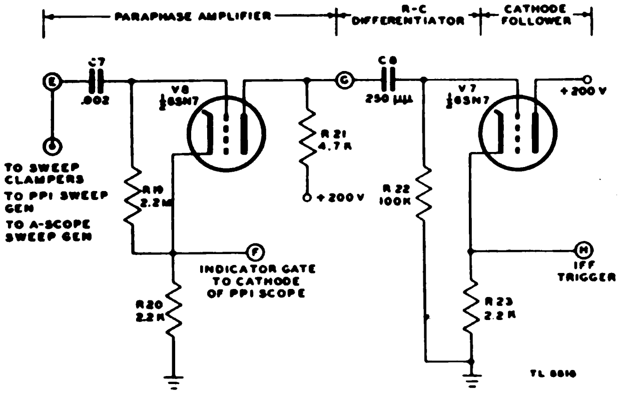


Figure 9

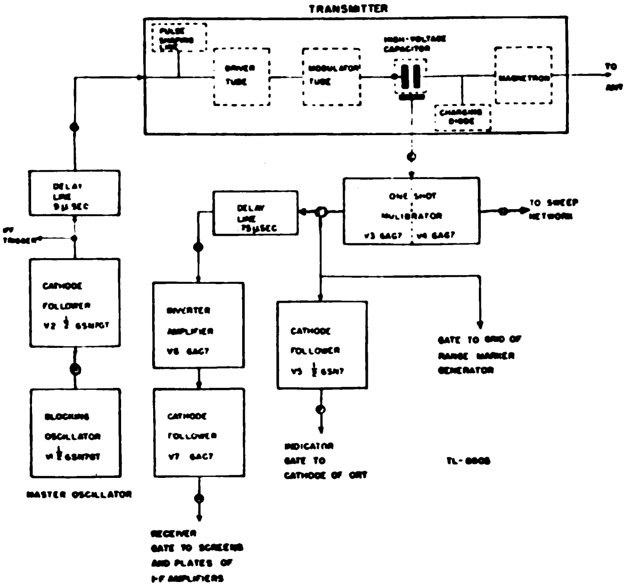


Figure 11

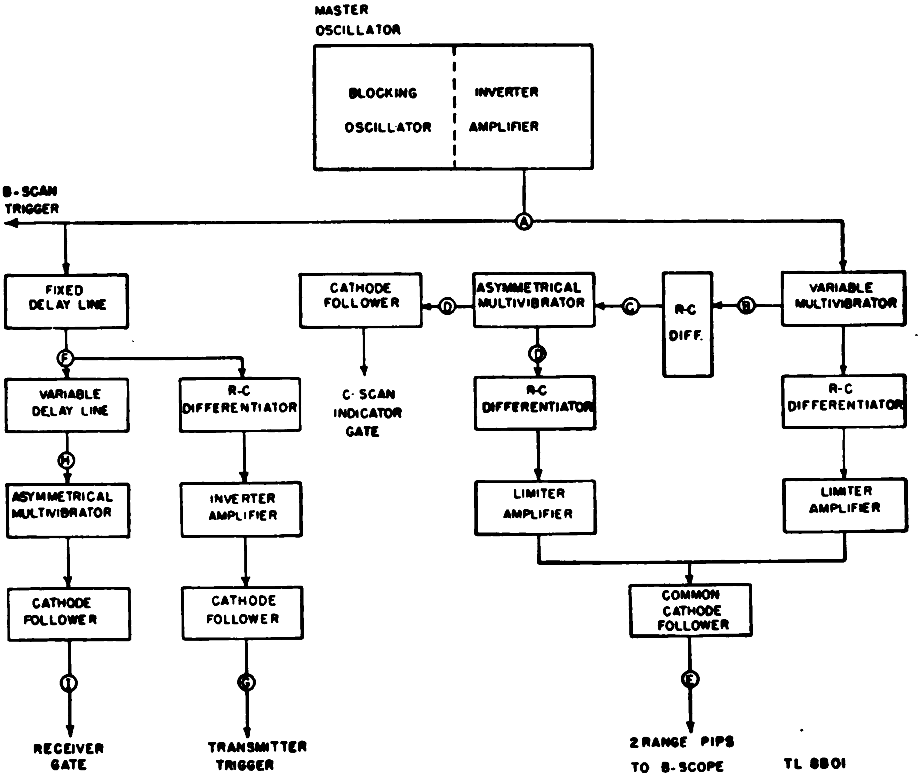


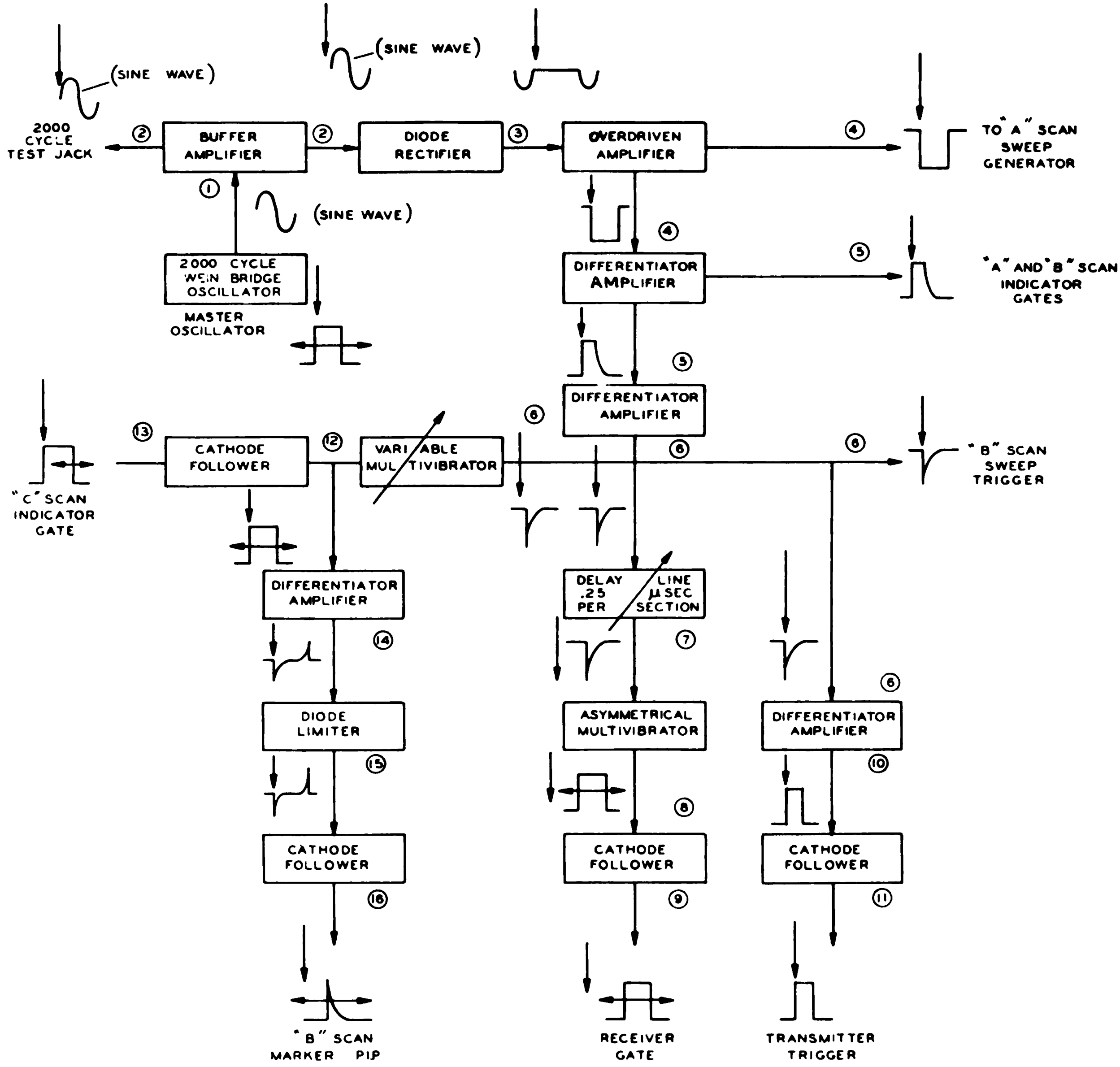
Figure 10

HOMEWORK SHEET No. 5

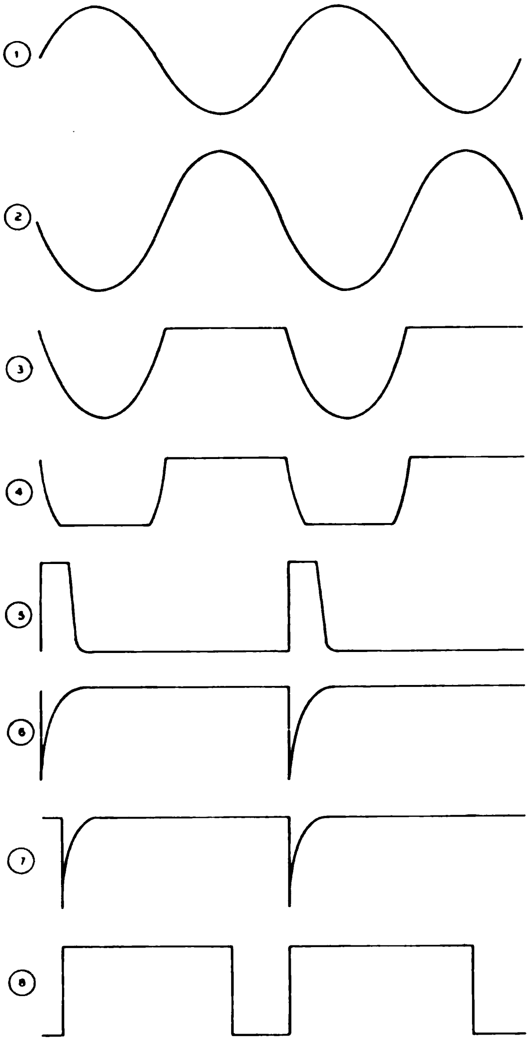
1. Collect all the notes you have taken on the sine-wave timer system. Prepare a block diagram of this system.

2. Draw a synchrogram of all waveforms drawn in connection with question 1. Be very careful to place the waveforms in proper time relationship with each other, and with the zero instant.

3. Prepare a series of block diagrams of the multivibrator timer. Include simplified block diagram of:



Suggested Drawing for Question 1



Suggested Drawing for Question 2

Master trigger generator.
"A" scope gate generator.
IFF trigger generator.
PPI gate generator.

4. For each of the blocks in question 1, prepare a separate sheet containing:

The input trigger waveform; indicate where this waveform is obtained.

The output waveform of each block.

A condensed statement of the function of each block.

5. Draw a synchrogram of all waveforms developed in the multivibrator timer system of question 3. Be very careful to place the waveforms in proper time relationship with each other and with the zero instant.

The following questions refer to the timer shown in Figures 5, 6, 7, 8, 9 of Lesson Plan No. 38.

6. b . A multivibrator-type timer is frequently used because:

a. It is much more accurate than is the sine-wave type or the blocking-oscillator type of timer.

b. It is simpler and lighter than the sine-wave timer.

c. It can be used for gun-laying equipment, whereas the sine-wave timer or the blocking-oscillator timer are suitable only for use in search gear.

d. It uses two tubes in the oscillator, and is, therefore, more reliable than types that use only one tube.

7. a, e . The positive pulses produced by a multivibrator timer are used to: (Choose all correct answers.)

a. Start the delay tube.
b. Blank the "PPI" indicator.
c. Blank the "A" scan indicator.
d. Blank the "B" scan indicator.
e. Trigger the peaking circuit of the "PPI" sweep generator.

8. a, b, c, d . The negative pulses of the multivibrator master oscillator are used to: (Choose all correct answers.)

a. Start the PPI sweep generator.
b. Start the "A" scope sweep generator.
c. Operate the synchronized clampers in the PPI sweep circuits.
d. Drive the paraphase amplifier.

9. a d . The master oscillator in the multivibrator timer operates at a p.r.f. of: (Choose all correct answers.)

a. 650 p.p.s. when the equipment is operating as radar search gear.
b. 650 p.p.s. when the equipment is taking a beacon bearing.
c. 325 p.p.s. when the equipment is operating as radar search gear.
d. 325 p.p.s. when the equipment is taking a beacon bearing.

10. c . The radar must be set to cover a longer range when taking a beacon bearing because:

a. Bearings are usually taken from distances greater than those used for ordinary search.

b. A longer resting period between pulses permits reception of a strong signal from the beacon. If a shorter resting time were used, the signal would be readable, but weak.

c. Neither of the above is correct. The radar must be set to cover a short range when receiving beacon signals.

11. c . Four different ranges (5, 20, 50, and

90 miles) are made available in this timer by:

a. Changing the time constant in the delay tube.

b. Changing the phase of the negative-going square wave as it passes through the paraphase amplifier.

c. Changing the time constants in the grid circuits of the multivibrator master oscillator.

d. None of the above is correct. This equipment operates on the 50-mile range only.

12. d . The function of the delay tube is:

a. To delay the IFF trigger for 9 microseconds after the main bang has started.

b. To delay the IFF trigger for 9 microseconds after the main bang has ended.

c. To delay the transmitter until after the receiver has been activated.

d. To delay the transmitter until after the IFF trigger has been applied.

13. d . The purpose of the paraphase amplifier is to:

a. Produce two square waves that are identical except that they are 180 degress out of phase with each other.

b. To produce two square waves, the second of which is delayed 10 seconds with respect to zero instant.

c. To produce two square waves, both of which are delayed with respect to zero instant.

d. None of the above is correct. The correct answer is:

To produce two square waves; one from the plate, to go to the differentiator, and one the cathode, to go to the indicator gate of the "PPI" scope.

14. c . Shaping of the square-wave outputs of the multivibrator into sharp pips is accomplished by means of:

a. Other multivibrators.

b. Delay tubes.

c. Differentiator amplifiers.

d. Cathode followers.

15. c . Blanking of the PPI scope is accomplished by applying:

a. A positive gate to the control grid of the cathode-ray tube.

b. A negative gate to the control grid of the cathode-ray tube.

c. A positive gate to the control of the cathode-ray tube.

d. A negative gate to the cathode of the cathode-ray tube.

16. Describe fully, but very concisely, the indirect-timing method described in Lesson Plan No. 38.

17. What is the particular advantage of the indirect-timing method of operation?

It exhibits repetition frequency stability. Also, simplicity is gained by utilizing the modulation pulse as a triggering voltage.

The following group of questions applies to the sine-wave timer described in Lesson Plan No. 38.

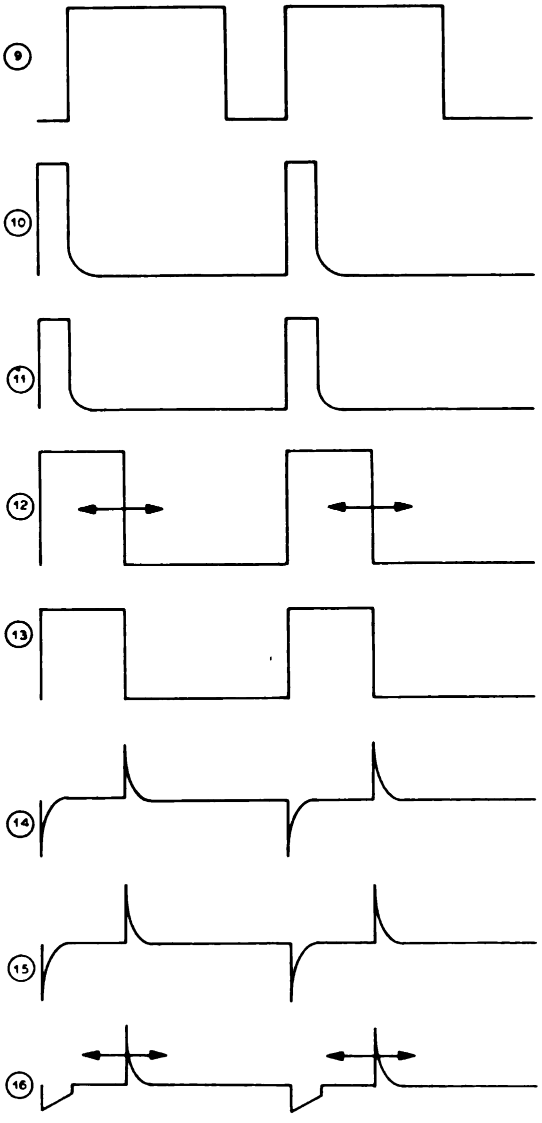
18. b, d, e . What three waveforms are obtainable at the output of the master trigger generator: (Choose all correct answers.)

a. A narrow positive-going master trigger pulse.

b. A narrow negative-going master trigger pulse.

c. A positive-going rectangular gate, to actuate the "A" scan sweep generator.

d. A positive-going gate, to unblank the



Suggested Drawing for Question 2

"A" and "B" scopes.

e. A negative-going gate, to actuate the "A" scope saw-tooth sweep.

f. A positive-going gate, to actuate the receiver during the sweep and to blank the receiver during the flyback time.

19. b . The receiver associated with this timer always goes into operation:

a. At the same instant at which the main bang starts.

b. At least 1 microsecond after the main bang starts.

c. At least 1 microsecond after the main bang ends.

d. At least 1 microsecond before the main bang starts.

20. a . The master trigger pulse and the "B" scan sweep trigger are the same pulse, exactly.

a. True.

b. False.

21. c . The receiver gate has a width:

a. Of exactly 122 microseconds.

b. Exactly equal to the resting time of the "A" scan sweep.

c. Which can be varied by the operator.

d. None of the above is correct.

22. b . The transmitter trigger:

a. Is delayed 1 microsecond after the instant when the master trigger pulse starts.

b. Starts at the same instant as the master trigger pulse.

c. Starts 1 microsecond before the start of the master trigger pulse.

23. d . The "B" scan marker pip occurs:

a. 122 microseconds before the master trigger pulse starts.

b. 122 microseconds after the master trigger pulse starts.

c. At the instant at which the master trigger pulse starts.

d. Can be adjusted to start at any desired time after the master trigger pulse starts.

24. d . The "C" scan indicator gate is intended to:

a. Keep the receiver from responding to echoes from altitudes higher than those it is desired to receive.

b. Keep the receiver from responding to echoes from altitudes lower than those it is desired to receive.

c. Blank the scope during the return of echoes from altitudes higher than those it is desired to receive.

d. Limit the range (in miles) of the "C" scope.

25. a . The master oscillator is a Wein-bridge type operating at 2000 cycles and producing an uninterrupted series of sine-waves.

a. True.

b. False.

26. b, c . The buffer amplifier: (Choose all correct answers.)

a. Acts as a frequency doubler, producing sinusoidal waves having a frequency of 4000 c.p.s.

b. Provides a constant load for the sine-wave oscillator.

c. Amplifies the sinusoidal output of the master oscillator.

d. Will affect the timing of the entire system, unless it is adjusted to have a negligible phase shift.

27. a, b . The diode limiter in the master trigger generator is used to: (Choose all correct answers.)

a. Remove the positive lobes of the input sine waves, thus keeping the grid of the following stage from being overloaded.

b. Start the squaring process that will eventually change sine waves into square waves.

c. Remove the negative lobes of the input sine waves, thus keeping the following tube from reaching current cutoff.

d. Clip both positive and negative lobes of the input sine wave, producing essentially square waves, to be fed to the following stage.

28. a, c . The overdriven amplifier in the master trigger generator: (Choose all correct answers.)

a. Converts the negative lobes of the input sine waves from the preceding stage into square waves.

b. Produces a positive-going gate pulse, to unblank the "A" scope.

c. Produces a negative-going gate pulse, to actuate the "A" scan sweep generator.

d. Produces a gate pulse that goes alternately positive and negative by equal amounts.

29. c . The first differentiator amplifier in the master trigger generator:

a. Produces a positive-going gate, to be applied to the indicator gate of the "C" scan.

b. Produces a negative-going gate, to actuate the sweep generator of the "C" scan.

c. Produces a positive-going indicator gate, to be applied to the control grids of the "A" and "B" scan scopes.

d. Produces sharply differentiated negative pips that are used as the master trigger pulse.

30. c . The second differentiator amplifier in the master trigger generator:

a. Is provided as a stand-by, in case of failure of the first differentiator amplifier.

b. Is a thyratron circuit, used in connection with an artificial transmission line to produce a time delay.

c. Produces a pulse known as the master trigger pulse.

d. Is a cathode follower, whose function is to prevent interaction between the first differentiator amplifier and the following stages.

31. d . The delay line of the receiver-gate generator is intended to:

a. Keep the main bang from starting before the receiver has been placed into operation.

b. Keep the receiver from starting before the main bang has started.

c. Keep the main bang from starting until a short interval after the receiver has been placed into operation.

d. Produce a variable delay to keep the receiver from starting until after the main bang has passed.

32. c . The asymmetrical multivibrator of the receiver-gate generator produces a positive-going gate that:

a. Starts at zero instant (t_0), and ends 122 microseconds later.

b. Is movable, but has a fixed width.

c. Has a leading edge and a trailing edge, both of which are adjustable.

d. Has a leading edge that occurs a few microseconds before zero instant, and a trailing edge that occurs a few microseconds after zero instant.

33. a, d . The output of the cathode follower in the receiver-gate generator is used to: (Choose all correct answers.)

a. Isolate the asymmetrical multivibrator from the receiver plate and screen circuits.

b. Deliver a negative voltage to the receiver plates and screens, in order to block the receiver during intervals when the "C" scan sweep is passing through the fly-back path.

c. Place the receiver into operation as soon as the main bang begins.

d. Place the receiver into operation as soon as desired after the main bang starts, and keep it in operating condition until the forward strokes of the "A" and "B" scan sweeps are both completed.

34. a . The grid circuit of the differentiator amplifier in the "B" scan marker generator produces:

a. Alternate negative and positive differentiated pips.

b. Movable positive pips only.

c. Movable negative pips only.

d. Positive and negative pips, both of which are movable.

35. d . The plate circuit of the differentiator amplifier circuit in the "B" scan marker generator:

a. Produces variable positive pips only.

b. Produces variable negative pips only.

c. Produces variable positive and negative pips.

d. Produces variable positive pips and stationary negative pips.

36. c . The diode limiter in the "B" scan marker generator:

a. Permits the marker pips to be given 10 times their normal pulse repetition frequency.

b. Eliminates the positive pips from the output of the differentiator amplifier.

c. Eliminates the negative pips from the output of the differentiator amplifier.

d. Eliminates the time delay inherent in the preceding circuits.

37. a . The output of the cathode follower fed by the diode limiter of question 19 is known as the "B" scan marker pip.

a. True.

b. False.

38. a, b, c, d . The differentiator amplifier in the transmitter trigger generator: (Choose all correct answers.)

a. Further differentiates the master trigger pulse fed to this stage.

b. Makes the leading edges of the transmitter trigger very sharp.

c. Inverts the master trigger pulses and produces a positive-going transmitter trigger.

d. Squares the tops of the transmitter trigger, through a process of current limiting.

39. a . The transmitter trigger generator employs a cathode-follower stage to isolate the differentiator amplifier from the transmitter stages.

a. True.

b. False.

40. b, d . The purpose of the variable multivibrator (V7) is to: (Choose all correct answers.)

a. Synchronize the output of the master trigger generator.

b. Introduce a variable delay in the edge of the square wave controlled by the master trigger pulse.

c. Introduce a variable delay that can be used to control the range (in miles) of the "C" scope.

d. Introduce a variable delay that can be used to calibrate the range marks on the "B" scope.

41. a . The "C" scan indicator gate generator is isolated from succeeding stages by means of a cathode follower.

a. True.

b. Fales.

EXAMINATION No. 8

1. c . The actual speed of a radar wave is:
   a. 186,000 statute miles per hour.
   b. 162,000 nautical miles per hour.
   c. 328 yards per microsecond.
   d. 1 statute mile per 10.7 microseconds.
   e. 1 nautical mile per 12.2 microseconds.

2. b . A radar scope uses a saw-tooth horizontal sweep having a duration of 73.2 microseconds. It is capable of showing targets at a maximum distance of:
   a. 1 mile.
   b. 6 miles.
   c. 12 miles.
   d. 60 miles.
   e. 100 miles.

3. b . It is necessary to use a sweep that traces across the scope a large number of times each second because:
   a. It is desired to keep a constant check upon the movements of the target.
   b. The scope will not display a bright image unless its phosphor is excited frequently by a beam of electrons.
   c. There is no way of keeping the sweep from starting every time the transmitter emits a pulse of energy.
   d. There is no way of keeping the transmitter from emitting a pulse of energy every time the sweep starts.

4. a . A single-lobe directional antenna produces a maximum echo from a distant target when the center line of the lobe:
   a. Passes directly through the target.
   b. Is aimed at an angle of 90 degrees to the line joining the observer and the target.
   c. Is aimed so as to pass above the target at an angle of 33-1/3 degrees.
   d. Is aimed directly away from the target.

5. d . The main factor limiting the highest carrier frequency that it is practical to use is:
   a. The frequency at which the klystron will oscillate.
   b. The frequency at which a magnetron can be made to oscillate.
   c. The size of the antenna necessary to produce a sharp beam.
   d. The attenuation of power at high frequencies, by atmospheric conditions, etc.
   e. None of the above is correct, there is no practical limit.

6. c . The principal factor limiting the lowest carrier frequency it is practical to use is:
   a. The frequency range over which the klystron will oscillate.
   b. The frequency range over which the magnetron will oscillate.
   c. The size of the antenna necessary to produce a sharp beam.
   d. The attenuation of power at low frequencies, due to ground radar systems.

7. b . The pulse width of a radar transmitter is:
   a. The width (in microseconds) of one individual cycle of the transmitter's oscillating output.
   b. The time which elapses between the instant when the transmitter begins to oscillate and the instant when it stops oscillating.
   c. The time which elapses between the instant when the transmitter stops oscillating and the instant when it resumes oscillating.
   d. The time which elapses between the instant when the transmitter stops oscillating and the instant when the first echo appears on the scope screen.

8. b . A certain radar has a pulse width of 0.8 microsecond, a carrier frequency of 3000 megacycles, and a pulse repetition frequency of 2000 p.p.s. The minimum range of this equipment is:
   a. Approximately 10 miles.
   b. Approximately .065 mile.
   c. 262.4 yards.
   d. Limited only by the curvature of the earth.

9. c . Average power, in radar equipments, is not:
   a. The reading of an r-f wattmeter connected to the output of the transmitter.
   b. The total power delivered by the system, averaged over a long period — for example, 1 second.
   c. Very high, compared with peak power.
   d. Calculated by the formula:

$$\text{Average power} = \frac{\text{Pulse width}}{\text{Pulse repetition time}}$$

10. d . A radar transmitter emits 0.5-microsecond pulses at a peak power of 1000 kilowatts. The pulse repetition frequency is 1500 p.p.s., the carrier frequency is 10,000 megacycles, and the maximum range of the equipment is 150 miles. The average power delivered by the transmitter is:
    a. .72 milliwatt.

b. 7.5 milliwatts.
c. 75 watts.
d. 750 watts.

11. d . The duty cycle of a radar transmitter is:
a. The time during which it is actually transmitting energy.
b. The time required for an echo to return from the most distant target it is desired to observe.
c. The ratio of the pulse width to the pulse repetition frequency.
d. The ratio of the average power to the peak power.

12. e . A radar transmitter has a duty cycle of .001, an average power of 300 watts, a pulse repetition frequency of 500 p.p.s., and a carrier frequency of 2500 megacycles. What is the peak power developed?
a. 17 watts.
b. 17 kilowatts.
c. 1.7 megawatts.
d. 30 kilowatts.
e. 300 kilowatts.

13. b . The pulse repetition frequency of radar systems is:
a. The time required for one complete cycle (pulse plus resting period).
b. The number of transmitter pulses occurring per second.
c. The highest frequency that can be used with a cathode-ray tube of a given persistence.
d. The lowest frequency that can be used with a cathode-ray tube of a given persistence.

14. a . In an "A" scope presentation, the horizontal axis represents:
a. Range.
b. Elevation.
c. Azimuth.
d. Velocity of the target.

15. d . In a "PPI" presentation, the horizontal axis represents:
a. Range.
b. Elevation.
c. Azimuth.
d. None of the above is correct. There is no horizontal axis.

16. a . In a "B" scope presentation, the vertical axis represents:
a. Range.
b. Elevation.
c. Azimuth.
d. Any two of these quantities may be selected for presentation on the vertical axis.

17. b . In a "B" scope presentation, range marks appear on the screen as:
a. Vertical lines, spaced along the horizontal axis.
b. Horizontal lines, spaced along the vertical axis.
c. Bright stationary spots, some distance above the horizontal axis.
d. Concentric rings.

18. d . In a "PPI" presentation, range marks appear on the screen as:
a. Vertical lines, spaced along the horizontal axis.
b. Horizontal lines, spaced along the vertical axis.
c. Bright stationary spots, some distance above the horizontal axis.
d. Concentric rings.

19. d . In a "PPI" presentation, azimuth marks appear on the screen as:
a. Vertical lines, spaced along the horizontal axis.
b. Horizontal lines, spaced along the vertical axis.
c. Bright stationary spots, some distance above the horizontal axis.
d. None of the above is correct.

20. d . In a "PPI" presentation, targets appear on the screen as:
a. Small pips, spaced along the horizontal axis.
b. Small pips, spaced along the vertical axis.
c. Small pips whose bases rest some distance above the horizontal axis.
d. Bright spots appearing anywhere on the scope except in the exact center.

21. e . In a "C" scope presentation, range marks appear on the screen as:
a. Vertical lines, spaced along the horizontal axis.
b. Horizontal lines, spaced along the vertical axis.
c. Bright stationary spots, located anywhere except on the horizontal axis.
d. Concentric rings.

e. None of the above is correct. There are no range marks on a "C" scope presentation.

22. b. In a self-synchronized radar system, timing pulses are produced by:

a. A separate unit, known as the timer chain.

b. The transmitter circuit itself, which acts as a master oscillator.

c. Neither of the above is correct. The source of timing pulses has nothing to do with determining whether a system is self-synchronized or externally synchronized.

d. None of the above is correct. A self-synchronized radar system does not use timer pulses at all.

23. a. In an externally synchronized radar system, timing pulses are produced by:

a. A separate unit, known as the timer chain.

b. The transmitter itself, which acts as a master oscillator.

c. Neither of the above is correct. The source of timing pulses has nothing to do with determining whether a system is self-synchronized or externally synchronized.

d. None of the above is correct. An externally synchronized radar system does not use timer pulses at all.

24. a, f, i, k. The timer may be called upon to supply any of the following timing pulses: (Choose all correct answers.)

a. A pulse to trigger the transmitter chain.

b. A pulse of r-f energy to be fed to the antenna.

c. A pulse of r-f energy to be fed to the receiver.

d. An r-f echo pulse.

e. A pulse of energy to actuate the T-R box.

f. A rectangular pulse of voltage, to be applied to the receiver plates and/or screens.

g. A video pulse, to be fed to the grid of the cathode-ray tube.

h. An antenna-positioning pulse.

i. A pulse to start the indicator sweep generator.

j. A pulse to blank out the indicator during the forward sweep of the saw-tooth voltage.

k. A pulse to block the grid of the marker generator during the forward sweep of the saw-tooth voltage.

25. d. The indicator gate is used to:

a. Make the receiver inoperative during the emission of the transmitter pulse.

b. Make the transmitter inoperative during the entire resting period.

c. Make the indicator inoperative during the entire resting period.

d. Make the indicator operative during the forward stroke of the sweep, and inoperative during the rest of the cycle.

26. d. A rotary spark gap is sometimes used in a radar system to:

a. Generate a pulse of r-f energy.

b. Establish a rigidly accurate timing pulse.

c. Form a rectangular modulator pulse of definite width.

d. Establish a moderately steady timing rate for the system.

LESSON PLAN No. 39

SUBJECT

The "A" scope indicator.

OBJECTIVE

To teach the theory of operation and to give applications of "A" type indicators.

MATERIAL REQUIRED

REFERENCE SHEETS 4-1, 4-2, and 4-3 (1 each per student).

INTRODUCTION

The "A" indicator, or range scope, is perhaps the most widely used presentation system. The "A" presentation is the least complex and the most trouble-free of all of the various radar presentations.

SUBJECT MATERIAL

1. Review, briefly, time and range measurements along a linear time base.

2. Draw and explain the type "A" presentations, showing trace, transmitter pulse, echoes, and range markers. (See REFERENCE SHEET 2-2).

3. Give each student a copy of the following sheets:

   a. Block Diagram, type "A" Indicator.
   b. Circuit Diagram, type "A" Indicator.
   c. Synchrogram, type "A" Indicator.

4. Draw, on the blackboard, the block diagram of the sweep circuits and the scope. (See REFERENCE SHEET 4-1.)

   a. Discuss the input and output waveforms of each block.

   b. Discuss the short-range and long-range switching arrangement. This will be covered more fully when the circuit diagram is explained.

5. Draw, on the blackboard, the schematic diagram of the sweep chain and scope. (See REFERENCE SHEET 4-2.)

   a. While discussing the theory of operation of the sweep chain, draw a synchrogram of all waveforms produced by the sweep chain, showing their relationship to the trigger input pulse. (See REFERENCE SHEET 4-3.)

   b. Discuss the method by which the gate pulse, from the one-shot multivibrator, V1, is made wider by inserting a larger capacitor in the long-range position of the range switch. Explain that the range switch is a two-position, three-gang switch.

   c. Explain that the reason for inserting a larger capacitor in the sweep generator, V2, in the long-range position of the switch is to hold the sweep amplitude constant with both the long-range and short-range conditions.

   d. Discuss unblanking, and show how it is accomplished in this circuit. Explain that the cathode-ray tube is cut off until the sweep starts; then the positive-going gate from the plate of V1B is applied to the grid of the cathode-ray tube, and this tube conducts, causing the trace to appear during the sweep time only; and that blanking of the tube is resumed after the gate passes, so that the retrace of flyback does not appear.

6. Draw, on the blackboard, the block diagram of the marker chain. (See REFERENCE SHEET 4-1.)

   a. Discuss the input and output waveforms of each block.

   b. Discuss the long-short range switching. Show how this switch is related to the contacts in the circuits of V1 and V2.

7. Draw, on the blackboard, the schematic diagram of the marker chain. (See REFERENCE SHEET 4-2.)

   a. While discussing the theory of operation of the marker chain, draw a synchrogram of all waveforms produced by the marker chain, showing their time relationship to the input trigger pulse and the gate waveform produced at the plate of V1B. (See REFERENCE SHEET 4-3.)

   b. Discuss the relationship of the frequency of the ringing oscillator output to the range in miles between marker pips.

   Discuss the formation of 1-mile and 5-mile markers by means of the range switch, which adds capacitance to the tank circuit on the long-range position.

   c. Explain that the output of V13, the marker chain, is then fed to a mixer circuit which combines the video and markers, and is then applied to the upper vertical deflection plate of the cathode-ray tube.

8. Draw, on the blackboard, the block diagram of the video chain. (See REFERENCE SHEET 4-1.)

   a. Discuss the input and output waveforms of each block.

   b. Explain the reasons for the use of each stage.

9. Draw, on the blackboard, the schematic diagram of the video mixer chain of V6 and V7. (See REFERENCE SHEET 4-2.)

a. Give a detailed explanation of the theory of operation of the mixer circuit of V7.

b. Show specifically how the video and markers are mixed.

c. Show the time relationship between the video and markers and the sweep and unblanking voltages.

10. Draw, on the blackboard, the complete block diagram of the "A" indicator. (See REFERENCE SHEET (4-1.)

a. Give a resume of the circuit tie-up.

b. Draw a complete synchrogram showing the relationship of all waveforms to the input trigger pulse from the timer.

CONCLUSIONS

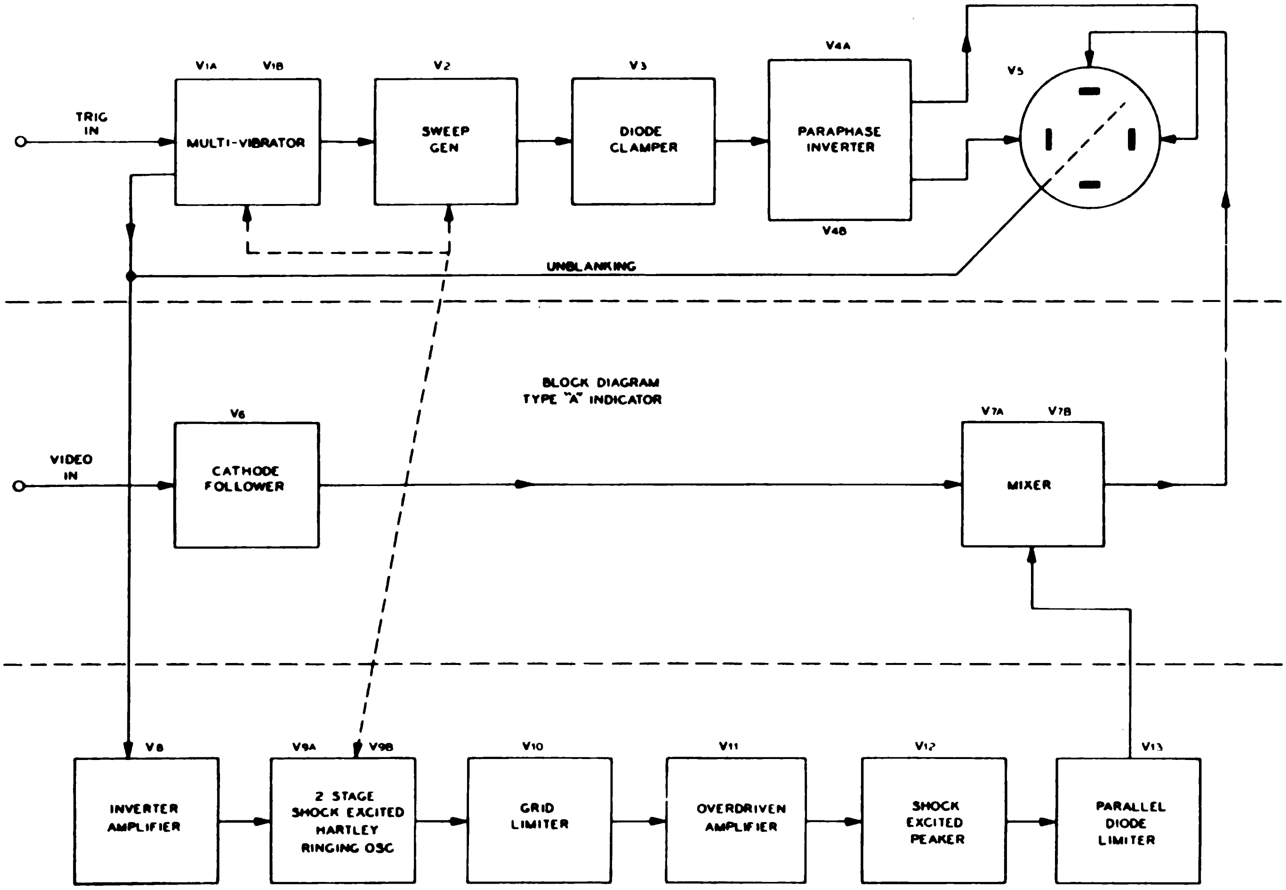
The "A" scan presentation incorporates a cathode-ray-tube indication with a horizontal or vertical sweep, giving range only. Signals appear as vertical or horizontal deflections on the time scale. This type of presentation is the least complex of the many used, and is often employed in conjunction with the PPI type of presentation.

ORAL QUIZ

1. Why is the range of the system increased by increasing the capacitance in the tank circuit of the master oscillator and associated capacitors in the sweep generator and the ringing oscillator?

2. By what process is the flyback trace on the screen of the cathode-ray tube kept from being seen?

3. What is the purpose of the cathode follower (V6) in the system?



Reference Sheet 4-1

HOMEWORK SHEET No. 6

The following questions apply to the "A" scan indicator described in REFERENCE SHEETS 4-1, 4-2, and 4-3, Use with LESSON PLAN NO. 39.

1. a . The trigger input waveform required (4-1) is a:

a. Narrow positive pip.
b. Narrow negative pip.
c. Positive-going rectangular wave.
d. Negative-going rectangular wave.

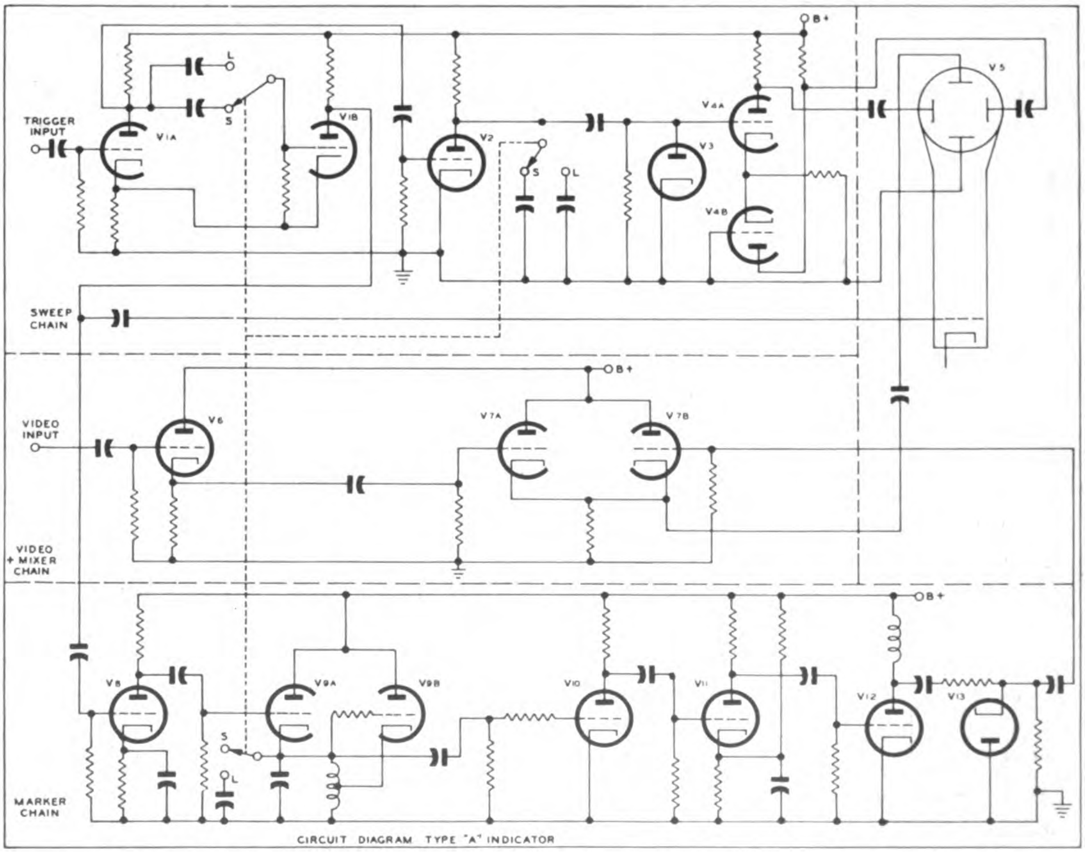
2. On REFERENCE SHEET 4-1, insert the proper waveforms at the output of each block. Indicate zero instant at the proper point on each waveform.

3. b . The purpose of the diode clamper is:

a. To maintain a constant voltage between the two grids of the paraphase amplifier.
b. To maintain the ungrounded grid of the paraphase amplifier at a negative voltage with respect to ground.
c. To maintain the ungrounded grid of the paraphase amplifier at a positive voltage with respect to ground.
d. To control the gain of the paraphase amplifier.

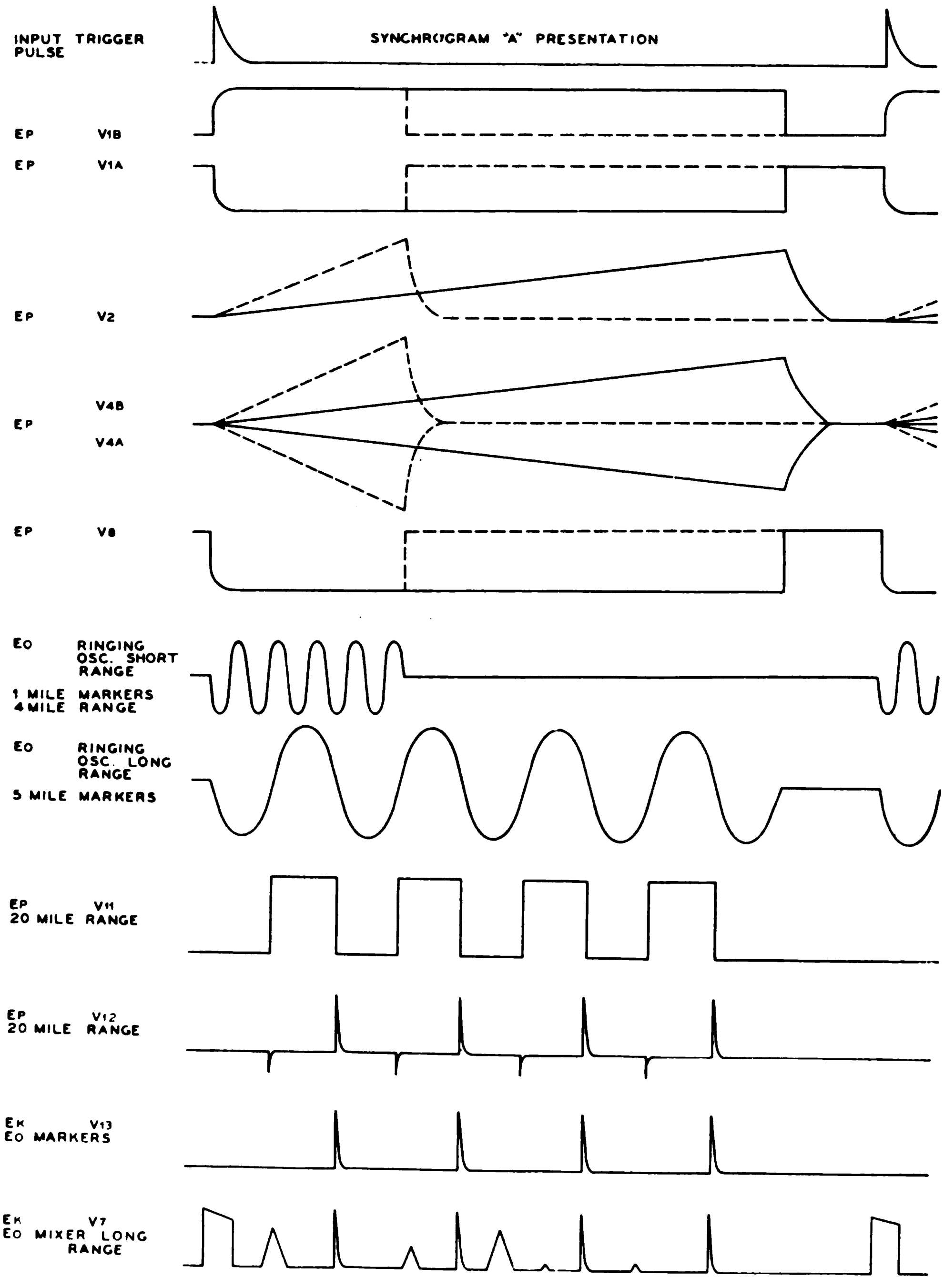
4. Describe briefly how the paraphase amplifier produces two waveforms that are 180 degrees out of phase.

This form of paraphase amplifier employs coupling between the cathodes of two tubes of the same type. Tube V4A is used as an amplifier, to increase the amplitude of the input signal to the desired level. Tube V4B is used as an inverter and amplifier, to produce a signal of the same amplitude, but of opposite polarity to the output of V4A. Since the grid of V4B is tied to ground, the amplitude of the effective voltage between grid and cathode of this tube is the voltage developed across the cathode resistor, which is equal to the input voltage to V4A. This has the effect of impressing on the grid of V4B a signal of opposite polarity but of the same amplitude as that impressed on V4A. Hence the 180° phase shift is produced.



CIRCUIT DIAGRAM TYPE "A" INDICATOR

Reference Sheet 4-2


INPUT TRIGGER PULSE
SYNCHROGRAM "A" PRESENTATION
EP V1B
EP V1A
EP V2
V4B
EP
V4A
EP V8
EO RINGING OSC. SHORT RANGE
1 MILE MARKERS 4 MILE RANGE
EO RINGING OSC. LONG RANGE
5 MILE MARKERS
EP V11 20 MILE RANGE
EP V12 20 MILE RANGE
EK V13 EO MARKERS
EK V7 EO MIXER LONG RANGE

Reference Sheet 4-3

5. a . The type of deflection used in this system is called:
   - a. Push-pull deflection.
   - b. Push-push deflection.
   - c. Paraphase deflection.
   - d. Trapezoidal deflection.

6. c . The video signals from the receiver are fed to the vertical-deflection plates of the scope through:
   - a. A paraphase amplifier.
   - b. A plate-coupled mixer.
   - c. A cathode-coupled mixer.
   - d. A grounded-grid amplifier.

7. d . Unblanking of the indicator scope is accomplished by the use of:

a. A square wave taken from the output of marker-chain tube V8.

b. A sharp negative pip taken from the input trigger connection.

c. One of the plates of the paraphase amplifier.

d. The plate of the one-shot multivibrator that is not used to actuate the sweep generator.

8. a . The function of V8, in the marker chain, is to:

a. Invert the negative-going pulse applied to its grid.

b. Invert the positive-going gate pulse applied to its grid.

c. Invert the positive-going pip applied to its grid.

d. Invert the negative-going pip applied to its grid.

9. d . The purpose of tube V9A is:

a. To disable V9B whenever a positive pip is applied to the grid of V9A.

b. To bring V9A into conduction whenever a negative gate is applied to the grid of V9A.

c. To allow V9B to function as a Hartley oscillator during the intervals when the grid of V9A is positive.

d. To damp out oscillations in the cathode inductance at all times except when the grid of V9A is negative.

10. d . The output waveform observed at the plate of V9B is:

a. A series of narrow positive-going pips.

b. A series of narrow negative-going pips.

c. A series of sine waves.

d. None of the above is correct.

11. a . The function of tube V10 is to:

a. Remove the positive alternations of the input sine wave.

b. Remove the negative alternations of the input sine wave.

c. Produce an inverted and amplified version of the signal appearing across the grid leak.

d. Shift the phase of the input waveform by not more than 90 degrees.

12. c . The cathode of tube V11 is operated:

a. At ground potential.

b. At a positive potential with respect to ground.

c. At a negative potential with respect to ground.

d. At a potential that will vary, depending upon the instantaneous voltage impressed upon the grid.

13. d . The purpose of V11 is to:

a. Amplify the sine waves impressed upon its grid.

b. Amplify and invert the sine waves impressed upon its grid.

c. Amplify and invert, without distortion, the square wave impressed upon its grid.

d. Introduce distortion into the waveform impressed upon its grid.

14. a . The input to V12 is:

a. A negative-going square wave.

b. A positive-going square wave.

c. A nearly symmetrical square wave, having a zero line that passes approximately through the middle of the wave.

d. A sine wave.

15. c . The purpose of V12 is to:

a. Convert the sine-wave input into a series of sine waves having a frequency much higher than the original input frequency.

b. Act as an impedance-coupled amplifier.

c. Convert the sharp negative pips applied to its grid into very sharp positive-going and negative-going marker pips having the same p.r.f. as the input trigger.

d. None of the above is correct. The circuit is a shock-excited peaking oscillator.

16. d . V13 is intended to:

a. Clamp the output of V12 positive with respect to zero.

b. Clamp the output of V12 negative with respect to zero.

c. Remove the positive pips present at the output of V12.

d. Remove the negative pips present at the output of V12.

17. d . The time interval between range marks (their distance apart, in "miles") can be increased by:

a. Removing a capacitor from one of the cathode circuits of the marker chain.

b. Changing the RC time constant of one of the grid circuits in the marker chain.

c. Increasing the LC product of one of the tank circuits in the marker chain.

d. None of the above is correct. The p.r.f. of the marker pips is adjusted by a switching arrangement in the one-shot multivibrator in the sweep chain.

LABORATORY PLAN No. 1

SUBJECT

Square-wave generator.

OBJECTIVE

To aid the student in testing a square-wave generator.

MATERIAL REQUIRED

NOTE: The distribution of the components in this section should be one per group (recommended to be two students) unless otherwise specified.

1. Square Wave Generator Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. Audio frequency oscillator with leads.
5. Five-inch oscilloscope with leads.
6. Vacuum-tube voltmeter with leads.

REFERENCES

Schematic diagram in EXPERIMENT No. 1.

INTRODUCTION

The square-wave generator to be used in the accompanying EXPERIMENT will be used extensively throughout the course. Therefore, good shop practice must be observed at all times in order to insure perfect operation of this chassis.

(The instructor should remind the students of the accepted practices that are required in a well-organized shop. He should give examples, familiar to him, of the results of poor laboratory technique in past experiences encountered in laboratories.)

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit a Square Wave Generator Chassis. Familiarize the class with each physical part, indicating the circuit symbols according to the schematic diagram.

2. Invite the class to ask questions.

Supervision

1. Check the tables of observed resistance and voltage readings. In the event that error exists, have the students determine the trouble and try to correct it themselves.

2. Discourage the students from entering readings in the tables just to fill in space. Insist that each reading be accurately taken, and that the result approximate the representative reading, before being entered in the table.

Adjustment

1. Conduct a demonstration showing the results expected in this section of the accompanying EXPERIMENT. Referring to the Adjustment section in the EXPERIMENT, follow the steps given there slowly enough so that the demonstration may be followed by each student.

2. Call attention to the procedure given in the INFORMATION SHEET on the measurement of non-sinusoidal voltages, for determining the peak voltage output of the square-wave generator.

3. Insist that all waveforms, and so forth, be neatly and accurately drawn. State that these drawings are obtained when the generator is operating properly, and that the value to the student, for future reference, will depend upon the accuracy with which they are recorded.

CONCLUSIONS

The square-wave generator tested gives a square-wave output of variable frequency, variable symmetry, and almost constant amplitude. Such a waveform is frequently used for timing, pulsing, and synchronizing other circuits, as will be brought out later in the course.

EXPERIMENT No. 1

SUBJECT

The square-wave generator.

OBJECTIVE

To test a square-wave generator, and insure that it is working properly.

MATERIAL REQUIRED

1. Square-Wave Generator Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. A-F oscillator with leads.
5. Five-inch oscilloscope with leads.
6. Vacuum-tube voltmeter with leads.

REFERENCES

Schematic diagram attached to this EXPERIMENT.

INSTRUCTIONS

The square-wave generator you are about to test will be used extensively within the next few weeks as a source of square waves.

Several pieces of equipment will be tested early in this course, in order that waveforms of the proper type may be studied. All this equipment will be considered in detail later, and the individual chassis will be incorporated in complete timer chains, sweep chains, and marker chains in the study of Advanced Electronic Systems.

It is important, therefore, that each chassis be tested carefully and accurately. After being approved by an instructor, these chassis are to be placed in the storage lockers provided. It will be the responsibility of each team of students to see that its chassis are available in good working condition, when needed later in the course.

Good laboratory technique at this point will avoid much future trouble and delay. The following precautions should be observed:

1. Check each connection as you proceed.

2. Always remove the tube when working on the back of an unmounted chassis. Miniature-tube pins bend easily, and the tube may be ruined if not carefully handled.

3. When storing a chassis at the conclusion of an EXPERIMENT, make sure that the standard plug-in parts specified in the attached schematic diagram and layout drawing are in place. Otherwise, you may waste time in some future EXPERIMENT before discovering the error.

PROCEDURE

Testing

1. Draw from supply, the items listed under MATERIAL REQUIRED.

2. With the chassis removed, make the resistance measurements indicated in TABLE 1. Insert the observed readings in the proper column.

3. Compare the observed readings with the representative readings listed in the table. If the two sets of readings do not agree reasonably well, try to determine the cause of the discrepancy and correct it. If the trouble cannot be located, consult an instructor.

4. Bolt the chassis to the rack. *Do not insert the tube.*

5. Make voltage measurements at the points indicated in TABLE 2, and insert the observed readings in the proper column.

6. Compare the observed readings with the representative readings listed in the table. If the two sets of readings do not agree reasonably well, try to determine the cause of the discrepancy and correct it. If the trouble cannot be located, consult an instructor.

Adjustment

1. When correct voltages are obtained, insert the 12AX7 tube in the tube socket, and connect the scope between the OUTPUT jack and ground.

2. Adjust the scope to present three cycles of the output waveform. Draw a sketch of this waveform in the space provided below, at figure 1.

Figure 1. Output Waveform

TABLE 1

RESISTANCES

OHMMETER CONNECTIONS	REPRESENTATIVE READINGS	OBSERVED READINGS
B plus and plate No. 1 (pin 1)	22,000 ohms	
B plus and plate No. 2 (pin 6)	22,000 ohms	
Grid No. 1 (pin 2) and chassis	3.2 megohms	
Grid No. 2 (pin 7) and chassis	3.2 meg	
Plate No. 1 and grid No. 2 (pins 1 and 7)	Infinity	
Plate No. 2 and grid No. 1 (pins 6 and 2)	Infinity	
INPUT jack and chassis	3.2 meg	
OUTPUT jack and chassis	Infinity	
Cathode No. 1. (pin 3) and chassis	Zero	
Cathode No. 2. (pin 8) and chassis	Zero	
Heaters (pins 9 and 5) and chassis	Infinity	

TABLE 2

VOLTAGES

VOLTMETER CONNECTIONS	REPRESENTATIVE READINGS	OBSERVED READINGS
B plus and chassis (pin 7 of adjacent rack receptacle and chassis	180—350 volts, d.c.	
Plate No. 1 (pin 1) and chassis	Same as B plus	
Plate No. 2 (pin 6) and chassis	Same as B plus	
Grid No. 1 (pin 2) and chassis	Zero	
Grid No. 2 (pin 7) and chassis	Zero	
Cathode (pin 3) and chassis	Zero	
Cathode (pin 8) and chassis	Zero	
Heaters (pins 9 and 5) (pins 9 and 4)	6.3 volts, a.c.	

3. By comparison with the output of an a-f oscillator, measure the output frequency of the square-wave generator.

a. With R6 equal to 1 meg.

b. After substituting a 100K resistor for R6.

Record the frequency in the space provided below.

Frequency 130 cycles.

4. Measure the peak voltage output of the square-wave generator by means of the scope, the v.t.v.m., and the a-f oscillator. (See the INFORMATION SHEET on the measurement of nonsinusoidal voltages.)

Peak voltage 25 volts, approximately

5. Adjust the square-wave generator for symmetrical square waves, according to the following procedure:

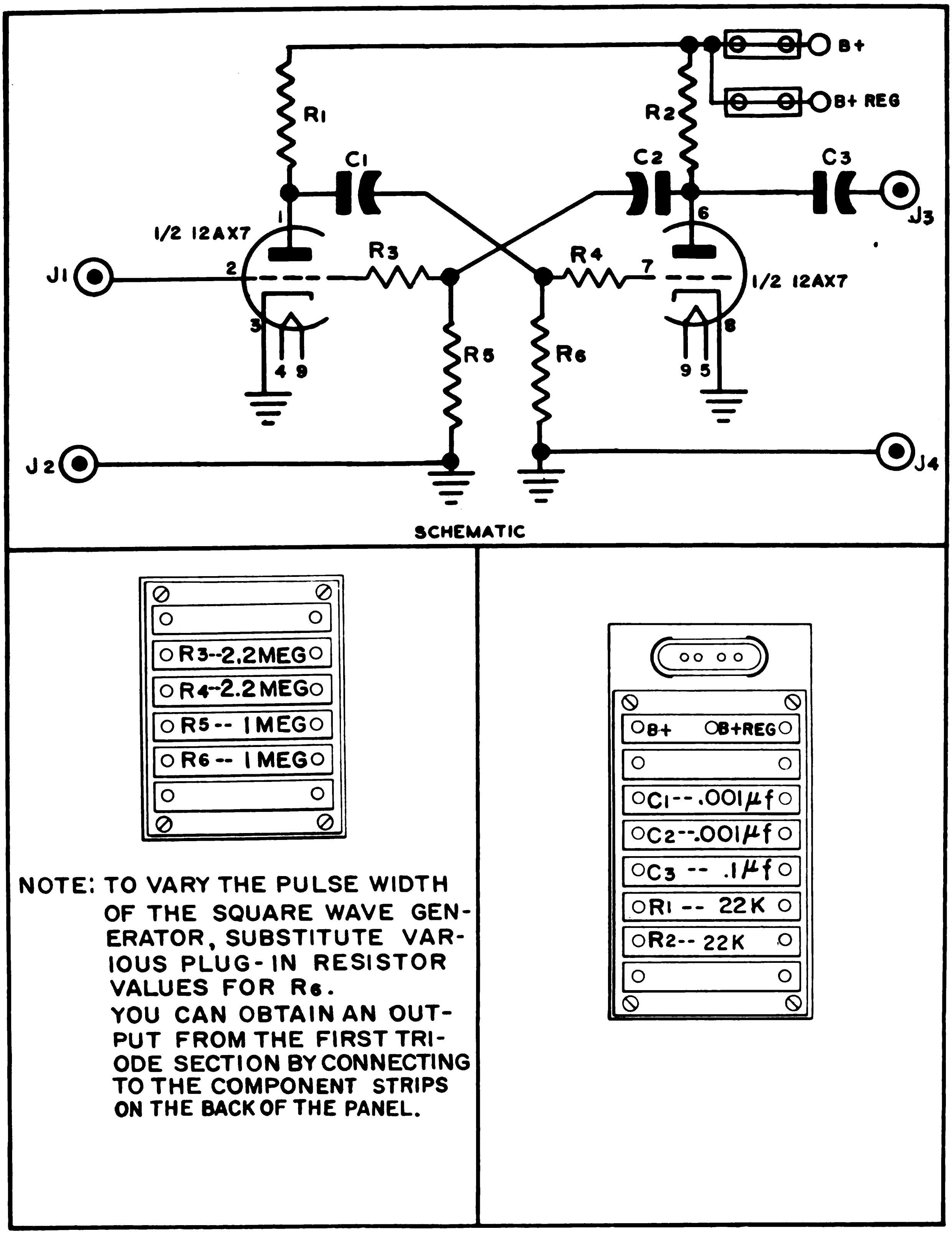
a. Connect the scope to the OUTPUT jack.

b. Adjust the scope to present three cycles of the square wave.

c. Move the trace up or down on the screen until one of the heavy horizontal lines falls halfway between the top and bottom of the square wave.

CHART SHOWING WIRE COLOR FOR EACH CIRCUIT

CIRCUIT	WIRE COLOR
B+	Red
Plate	Blue
Control Grid	Green
Cathode	Bare Wire
Heater	Brown
Ground	Bare Wire



NOTE: TO VARY THE PULSE WIDTH OF THE SQUARE WAVE GENERATOR, SUBSTITUTE VARIOUS PLUG-IN RESISTOR VALUES FOR R6. YOU CAN OBTAIN AN OUTPUT FROM THE FIRST TRIODE SECTION BY CONNECTING TO THE COMPONENT STRIPS ON THE BACK OF THE PANEL.

Schematic Diagram of Square-Wave Generator Chassis

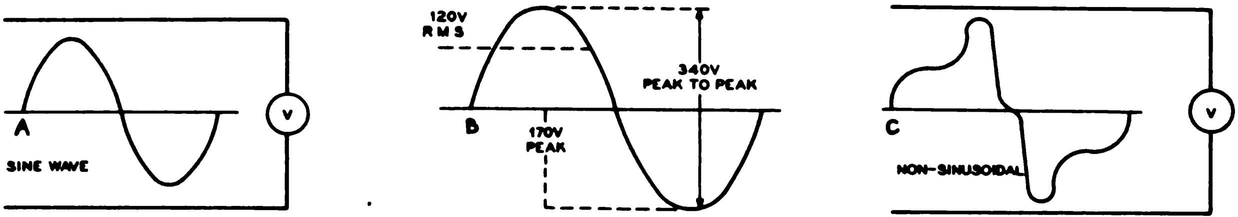
INFORMATION SHEET

VOLTAGE MEASUREMENTS ON NON-SINUSOIDAL WAVEFORMS

In order to measure the effective (r-m-s) voltage of a sine wave from an a-f oscillator, commercial power line, etc., it is only necessary to connect an a-c volt-meter across the source and read the effective voltage directly from the meter scale (figure 1A).

If the peak value is desired, instead of the r-m-s value, multiply the meter reading by 1.414. To obtain the peak-to-peak amplitude, multiply the r-m-s reading by 2.828 (figure 1B).

But non-sinusoidal waveforms cannot be handled so easily. Most a-c meters are calibrated to work on sine-wave input, only. If the waveform of the voltage across which they are connected is square, triangular, or some other irregular shape, the meter reading obtained will be incorrect, and will give very little information about the waveform being measured (figure 1C).



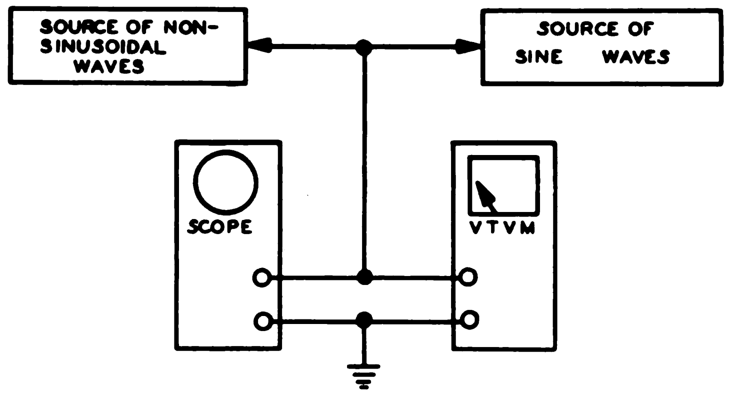
METER READS 120 VOLTS R M S (120 X 1.414=170V PEAK. 120 X 2.828 =340V PEAK TO PEAK.)

PEAK AMPLITUDE OR PEAK TO PEAK AMPLITUDE CAN BE CALCULATED FROM R M S AMPLITUDE OF A SINE WAVE.

METER READS TRUE R M S VALUE, BUT PEAK VALUE IS NO LONGER 1.414 TIMES R M S VALUE.-(THIS RELATION HOLDS ONLY FOR SINE WAVES.)

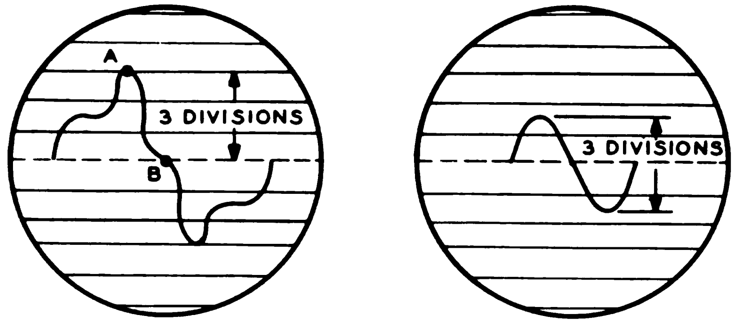
Figure 1. Curves Showing Why A-C Meter Cannot Be Used to Measure Peak Amplitudes of Non-sinusoidal Waveforms

All the data required, however, can be easily obtained with the aid of an oscilloscope, a voltmeter, and a source of sine waves. The method is simple. The sine-wave amplitude is adjusted until it produces an oscilloscope trace of the same height as the distance between the center line and the peak of the trace produced by the non-sinusoidal wave. A voltmeter is used to measure the r-m-s value of the sine wave. This r-m-s reading is converted to the peak-to-peak value by multiplying it by 2.828. The resultant peak-to-peak voltage value is the desired answer — It is the peak amplitude of the non-sinusoidal waveform.



Example: With the sine-wave source adjusted to produce a 3-division deflection, v.t.v.m. reads 20 volts, rms. A-F wave has peak-to-peak amplitude of 20 x 2.828 = 56.56 volts. Peak amplitude of non-sinusoidal wave is also 56.56 volts.

Figure 2. Block Diagram of Equipment Used for Measuring Amplitude of Non-sinusoidal Waveforms



A
POSITIVE PEAK IS 3 DIVISIONS ABOVE ZERO AXIS

B
ADJUST A-F OSCILLATOR OUTPUT UNTIL PEAKS ARE 3 DIVISIONS APART

Measure r-m-s value of sine wave by placing a v.t.v.m. across a-f oscillator terminals. Multiply observed voltage by 2.828. This gives the voltage represented by a deflection of 3 scope divisions.

Figure 3. Easy Method of Measuring Amplitude of Non-sinusoidal Waveforms

The procedure is as follows:

1. Connect an oscilloscope across the voltage. to be measured, as shown in figure 2, and adjust the scope controls to display one cycle of the waveform (figure 3A).

2. Adjust the scope trace until it fills most of the screen.

> NOTE: Make no further adjustment of the oscilloscope controls until the measurement is finished; otherwise, error will result.

3. Measure the distance on the screen between the points on the trace whose *voltage difference* you wish to measure. (Points A and B, for example, in figure 3A.) Use a ruler, a piece of graph paper, or a cross-section screen.

4. Disconnect the voltage source being measured, and connect the scope across the output of an a-f oscillator.

5. Adjust the oscillator until a stationary cycle of its sine wave appears on the scope screen.

6. Adjust the output voltage of the oscillator until the peaks are exactly the same distance apart (vertically) as the distance measured in step 3. See figure 3B. The peak-to-peak amplitude of the sine wave is now equal to the voltage difference it is desired to measure.

7. Connect a vacuum-tube voltmeter across the a-f oscillator terminals, and read the voltage being delivered. Remember that the meter reads *r-m-s* voltage.

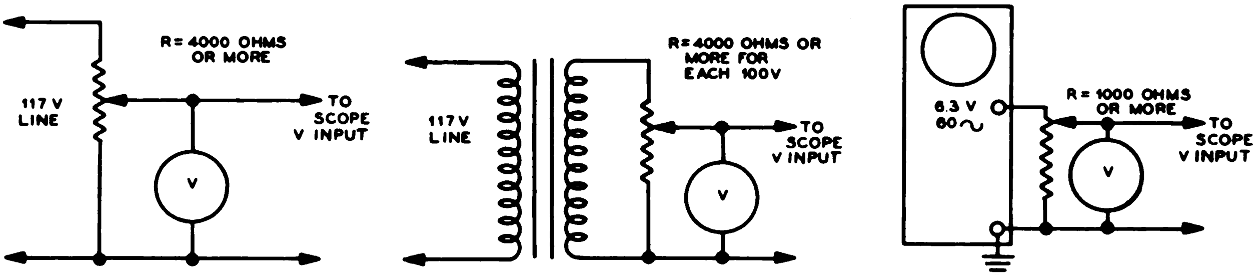
8. To convert this r-m-s reading to the peak-to-peak voltage, multiply the meter reading by 2.828.

9. This peak-to-peak amplitude is the voltage existing between the two points (A and B) on the non-sinusoidal wave being measured.

A vacuum-tube voltmeter is recommended for use in this type of measurement. If a v.t.v.m. is not available, a lower-resistance meter may be used, but it must be left connected across the sine-wave voltage source at all times.

An audio-frequency oscillator is recommended as the source of sine waves, because of the purity of the sine waves produced by most a-f oscillators and because of the ease with which their output voltage can be adjusted. In some cases, however, an oscillator may not be available. Or it may be impossible to obtain from the oscillator a sine wave of sufficient amplitude to equal the amplitude of the non-sinusoidal wave being measured. In such cases, it is quite satisfactory to use a filament transformer, a high-voltage transformer, or the a-c test voltage provided at a binding post on some oscilloscopes, or to connect directly across the commercial power line as a source of sine-wave voltage. The use of a voltage-divider network will permit sine-wave voltage of any reasonable amplitude to be obtained from these sources. (See figure 4.)

After a little practice with this method of measurement, it will become evident that, while it is *desirable* to have the peak-to-peak value of the sine wave equal the voltage difference being measured, this is not altogether necessary. If the a-f oscillator produces a peak-to-peak voltage of only 50 volts, and the non-sinusoidal waveform under measurement has a peak value of 80 volts, it can still be measured with fair accuracy. Simply adjust the sine-wave amplitude until its peak-to-peak trace is *half* as high as the trace produced by the non-sinusoidal wave. Measure the r-m-s value of the sine wave, calculate its peak-to-peak amplitude as before, then ***multiply this value by 2*** (because the sine-wave trace has been deliberately adjusted to half the amplitude of the non-sinusoidal trace). Most oscilloscopes are sufficiently linear in their response to give reasonably accurate results by this method.



POTENTIOMETER ACROSS THE POWER LINE

POTENTIOMETER ACROSS A POWER TRANSFORMER

POTENTIOMETER ACROSS THE SCOPE TEST TERMINALS

Figure 4. Other Methods of Obtaining a Sine Wave of Adjustable Amplitude

LABORATORY PLAN No. 2

SUBJECT

The saw-tooth generator.

OBJECTIVE

To supervise the testing and adjustment of a saw-tooth generator.

MATERIAL REQUIRED

1. Saw-tooth Generator Chassis.
2. Square Wave Generator Chassis.
3. Laboratory Chassis Mounting Rack.
4. Power Supply Chassis.
5. A-F oscillator with leads.
6. Five-inch oscilloscope with leads.
7. Vacuum-tube voltmeter with leads.

REFERENCES

Schematic diagram and layout drawing accompanying the EXPERIMENT.

INTRODUCTION

In this EXPERIMENT, the student will test a saw-tooth generator chassis for use in the early part of the course. The detailed circuit operation of this chassis will be considered in a later EXPERIMENT.

(At this point, the instructor should call attention to some of the errors and poor practices observed by him during previous laboratory sessions.)

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit a Saw-tooth Generator Chassis. Point out each physical part, and indicate the circuit symbol (R1, C2, and so forth) by which it is designated on the schematic diagram.
2. Invite the class to ask any questions they wish concerning the chassis.

Supervision

Check the tables of observed resistance and voltage readings. Lead the students to determine the possible causes of any discrepancies, and encourage them to use standard trouble-shooting procedure in clearing up the trouble.

Adjustment

1. Conduct a demonstration of the results expected in the Adjustment section of the accompanying EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there. Perform this demonstration slowly enough to be followed by the class, and avoid excessive theoretical explanation.

2. Call attention to the fact that two chassis (the square-wave generator and the saw-tooth generator) are connected together in this EXPERIMENT. Warn the class that incorrect wave shape or amplitude in the square-wave-generator output can prevent the saw-tooth generator from performing correctly.

3. Keep a close check on the waveforms being obtained, and help the students to correct those that are not suitable. The class has not yet studied the saw-tooth generator circuit, and cannot be held responsible for any knowledge of the chassis aside from what has been taught during this EXPERIMENT.

4. Insist upon neat, carefully drawn waveforms. Remind the class that these are the actual waveforms obtained when the equipment is operating properly. They may differ widely from idealized waveforms found in many textbooks. They should, therefore, be reproduced exactly as they appear on the screen, in order that the student may, in later EXPERIMENTS, compare the waveforms he is obtaining with those that are known to be correct.

CONCLUSIONS

The saw-tooth generator is one of many circuit arrangements used to produce a saw-tooth output. The advantage of this type of circuit over those using neon-filled or thyratron gas tubes is that its frequency stability may be made as good as that of the input triggering circuit.

EXPERIMENT No. 2

SUBJECT

The saw-tooth generator.

OBJECTIVE

To test a saw-tooth generator, and to observe the characteristics of its output waveform.

MATERIAL REQUIRED

1. Saw-tooth Generator Chassis.
2. Square Wave Generator Chassis.
3. Laboratory Chassis Mounting Rack.
4. Power Supply Chassis.
5. A-F oscillator with leads.
6. Five-inch oscilloscope with leads.
7. Vacuum-tube voltmeter with leads.

REFERENCES

Schematic diagram and layout drawing attached to this EXPERIMENT.

INSTRUCTIONS

The saw-tooth generator to be tested in this EXPERIMENT will be used during the early part of this course. Its operation will be studied in detail in a later EXPERIMENT. As in the case of the square-wave generator, the saw-tooth generator will be used frequently throughout the course.

PROCEDURE

1. Study the schematic diagram and layout drawing attached to this EXPERIMENT.

2. Using the ohmmeter, make the resistance measurements indicated in TABLE 1 (with the sawtooth generator out of the rack and the tube removed). Insert the observed readings in the proper column.

3. Compare the observed readings with the representative readings listed in the table. If the two sets of readings do not agree reasonably well, try to determine the cause of the discrepancy and correct it. If the trouble cannot be located, consult an instructor.

4. Mount in rack and turn on power. Make voltage measurements at the points indicated in TABLE 2, and insert the observed readings in the proper column.

TABLE 1

RESISTANCES

OHMMETER CONNECTIONS	REPRESENTATIVE READINGS	OBSERVED READINGS
B plus and plate (pin 1)	1 megohm to 2 megohms (depending upon potentiometer setting)	
Grid (pin 6) and chassis	1 megohm	
Plate (pin 1) and OUTPUT jack	Infinity	
Cathode (pin 7) and chassis	Zero	
Heaters (pins 3 and 4) and chassis	Infinity	

TABLE 2

VOLTAGES

VOLTMETER CONNECTIONS	REPRESENTATIVE READINGS	OBSERVED READINGS
B plus and chassis	200—350 volts, d.c.	
Plate (pin 1) and chassis	Same as B plus	
Grid (pin 6) and chassis	Zero	
Cathode (pin 7) and chassis	Zero	
Heaters (pins 3 and 4)	6.3 volts, a.c.	

5. Compare the observed readings with the representative readings listed in this table. If the two sets of readings do not agree reasonably well, try to determine the cause of the discrepancy and correct it. If the trouble cannot be located, consult an instructor.

Adjustment

1. Mount the square-wave generator on the rack beside the saw-tooth generator.

2. Insert the 6AB4 tube in the Saw-tooth Generator Chassis. Set up the square-wave generator, the saw-tooth generator, and the scope as shown in the block diagram on page 155.

3. Select a value for R6 which will produce wide negative pulses.

4. Connect the scope input lead to OUTPUT jack J3 on the Square-Wave Generator Chassis, and make sure that the required waveform is being generated.

5. Return the scope lead to the output of the saw-tooth generator, and adjust the scope until three cycles of the output waveform appear on the screen.

6. Measure the peak voltage output of the saw-tooth generator by means of the scope, the v.t.v.m., and the a-f oscillator. (See the INFORMATION SHEET on the measurement of non-sinusoidal voltages.)

Peak voltage output, ________volts

Study of Waveforms Available

1. With a value of R6 in the square-wave generator which will produce a wide negative pulse, and with the saw-tooth-generator potentiometer set at mid-position, carefully observe the waveform obtained on the scope. Draw to scale two cycles of this waveform in the space provided at B of TABLE 3.

TABLE 3

WAVEFORMS AVAILABLE FROM SAW-TOOTH GENERATOR

A Wide Negative Input Pulses, Narrow Positive Spikes, Potentiometer Counterclockwise	D Symmetrical Square-Wave Input, Potentiometer Counterclockwise
B Wide Negative Input Pulses, Narrow Positive Spikes, Potentiometer at Mid-scale	E Symmetrical Square-Wave Input, Potentiometer at Mid-scale
C Wide Negative Input Pulses, Narrow Positive Spikes, Potentiometer Clockwise	F Symmetrical Square-Wave Input, Potentiometer Clockwise

2. Turn the saw-tooth-generator potentiometer as far counterclockwise as possible without stopping oscillation, and trace the resulting waveform at A in TABLE 3.

3. Turn the potentiometer as far clockwise as possible without stopping oscillation, and trace the resulting waveform at C in TABLE 3.

4. Now use a value of R6 in the square-wave-generator which gives an approximately symmetrical square-wave output.

5. Reconnect the scope lead to the output jack of the saw-tooth generator, and observe the waveform obtained.

6. At D, E, and F, in TABLE 3, draw to scale two cycles of the waveform obtained with the saw-tooth-generator potentiometer in the counterclockwise, mid-scale, and clockwise positions, respectively.

CONCLUSIONS

1. What effect does varying the saw-tooth-generator potentiometer have upon:

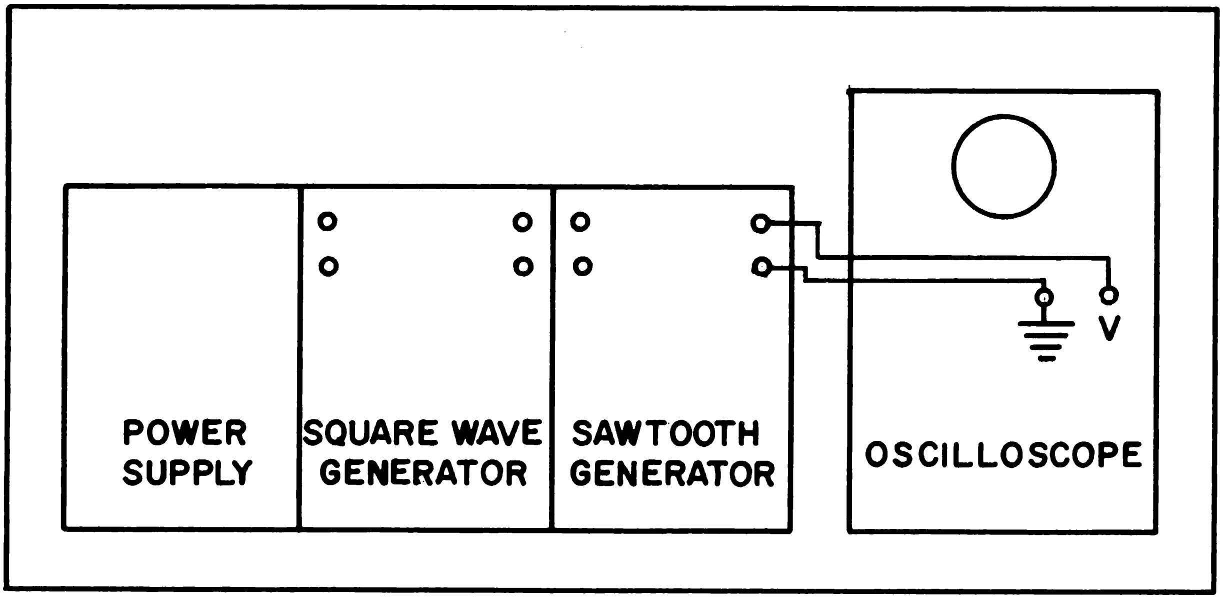
   a. The frequency of the saw-tooth wave?

   b. The amplitude of the saw-tooth wave?

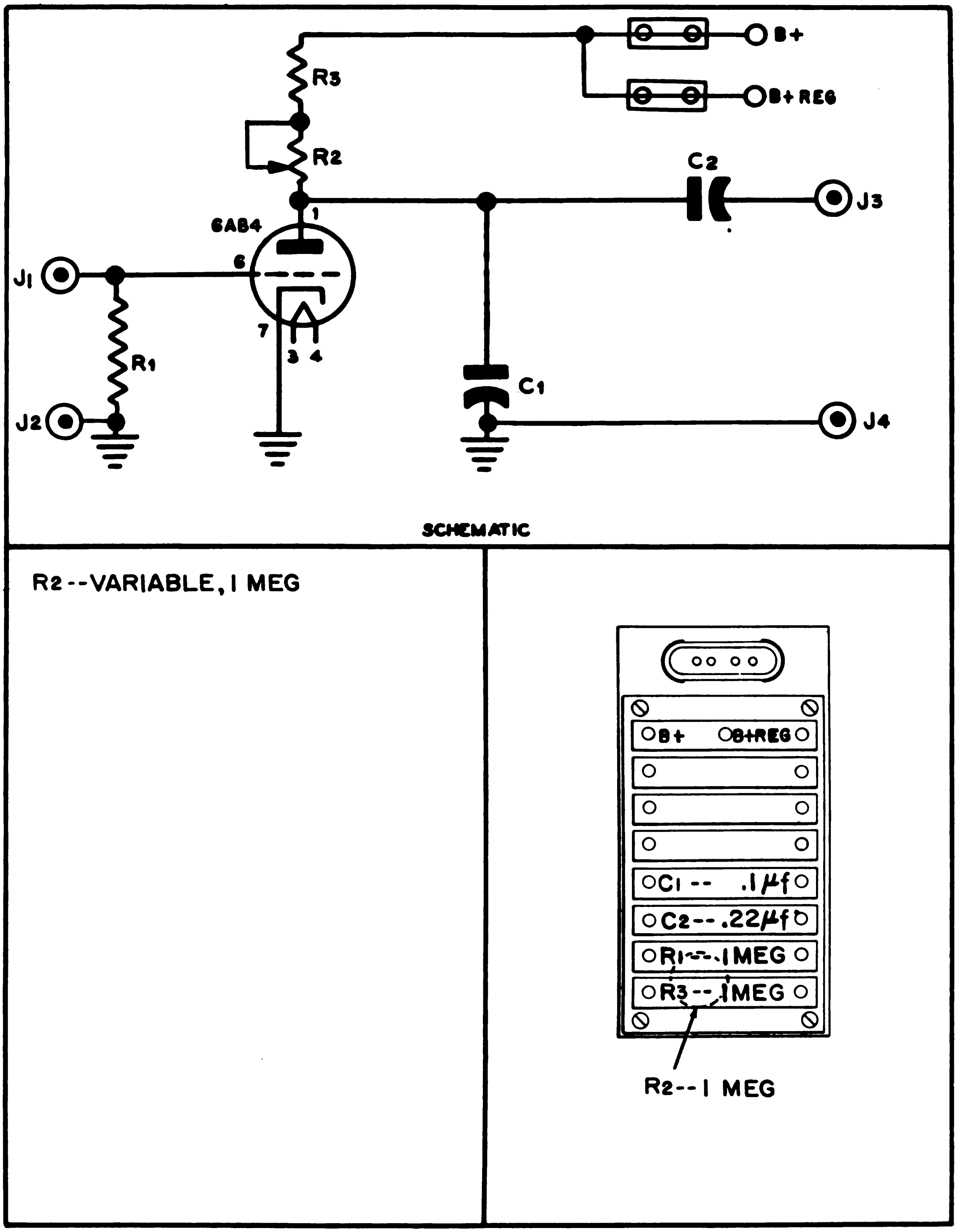
   c. The shape of the saw-tooth wave?

2. What effect does changing the width of the input square wave have upon the shape of the saw-tooth? Does a narrow spike or a broad, symmetrical square-wave input produce greater linearity in the rising portion of the saw-tooth?

3. Describe any difficulties encountered in making the saw-tooth generator operate properly. What measures were taken to overcome these difficulties, and what were the results?



Block Diagram of Equipment Setup for Adjustment of Saw-tooth Generator



Schematic Diagram of Vacuum Tube Saw-tooth Generator Chassis

LABORATORY PLAN No. 3

SUBJECT

The R-C oscillator.

OBJECTIVE

To supervise the testing of an R-C sine-wave oscillator; and to supervise the study of the characteristics and operation of this oscillator.

MATERIAL REQUIRED

1. R-C Oscillator Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. A-F oscillator with leads.
5. Five-inch oscilloscope, with leads and cross-section screen.
6. Vacuum-tube voltmeter with leads.
7. Additional plug-in parts as follows:
    - Resistor, 4700 ohms.
    - Resistor, 10,000 ohms.
    - Resistor, 47,000 ohms.
    - Resistor, 470,000 ohms.
    - Resistor, 1.0 megohm.

INTRODUCTION

The R-C Oscillator Chassis to be used in this EXPERIMENT is typical of many of the oscillators used in practical radar equipments. One precaution is necessary in using this chassis: a cathode follower must sometimes be employed as an isolation device between the oscillator and the following chassis. This oscillator circuit will be used as a source of sine waves for the remainder of this course. Its ability to fit into a typical radar chain makes it an important circuit in the system.

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit an R-C Oscillator Chassis. Refer to each part by name, indicating the symbol by which it is designated on the schematic diagram.

2. Call attention to the table in the EXPERIMENT, and stress the importance of obtaining accurate measurements of the voltages and waveforms produced. These measurements will be useful, in later EXPERIMENTS, in determining whether the chassis is still operating properly.

Trouble Shooting

1. At the proper time, call the class together and demonstrate the procedure to be used in carrying out the EXPERIMENT. Lay special emphasis upon the method of measuring non-sinusoidal voltages, as described in the INFORMATION SHEET on this subject.

2. Conduct a class discussion on trouble-shooting methods applicable to this equipment. Lead the class in the preparation of a list of possible causes, tests, and remedies for lack of output voltage, and for distorted output waveform.

CONCLUSIONS

In this type of oscillator, the frequency is determined by a resistance-capacitance network instead of a tuned-circuit arrangement. The R-C network provides positive feedback between the output and input of the one-tube amplifier.

EXPERIMENT No. 3

SUBJECT

The R-C oscillator.

OBJECTIVE

To test an R-C sine-wave oscillator for use in radar chains; to make voltage and waveform measurements on this chassis, for use in trouble shooting, should faults develop later; to study the characteristics of this oscillator, including the waveform produced, the frequency range available, and the peak amplitude to be expected.

MATERIAL REQUIRED

1. R-C Oscillator Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. A-F oscillator with leads.
5. Five-inch oscilloscope, with leads and cross-section screen.
6. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

The R-C Oscillator Chassis is used throughout this course as a source of sine waves. In many cases it is preferred to the laboratory-type audio-frequency oscillator, because it fits into a typical radar chain and introduces interconnection problems typical of such chains. It is characteristic of this oscillator that its output circuit can be overloaded very easily, resulting in a decrease in amplitude of the output sine waves. This effect can be overcome by the use of a cathode follower, which will be studied in a later EXPERIMENT.

PROCEDURE

1. Study the schematic diagram attached to this EXPERIMENT.
2. Bolt the chassis to the rack. *Do not insert the tube.*

Testing

1. With the tube removed from the socket, make the voltage measurements indicated, and insert the observed readings in the proper column.

Operational Check

1. Insert the tube in the R-C Oscillator Chassis, and apply the power.
2. Connect the scope lead to the OUTPUT jack.
3. Set R4 to its mid position and vary R3 over the entire range that will produce oscillation, and measure the output frequency by comparison with that of an a-f oscillator.

Frequency______ to ______cycles

Trouble Shooting

1. Change the plate load resistor, R5, to 10,000 ohms, and record in the accompanying table the d-c plate voltage, d-c screen voltage, a-f output voltage, a-f grid voltage, and output waveform.

2. Repeat step 1, using plate load resistors of 47,000 ohms, and 100,000 ohms.

3. Replace R5 with the 100K resistor. The R-C oscillator now carries the plug-in parts shown in the diagram, and is ready for use later in the course, when it will be inserted in various radar chains.

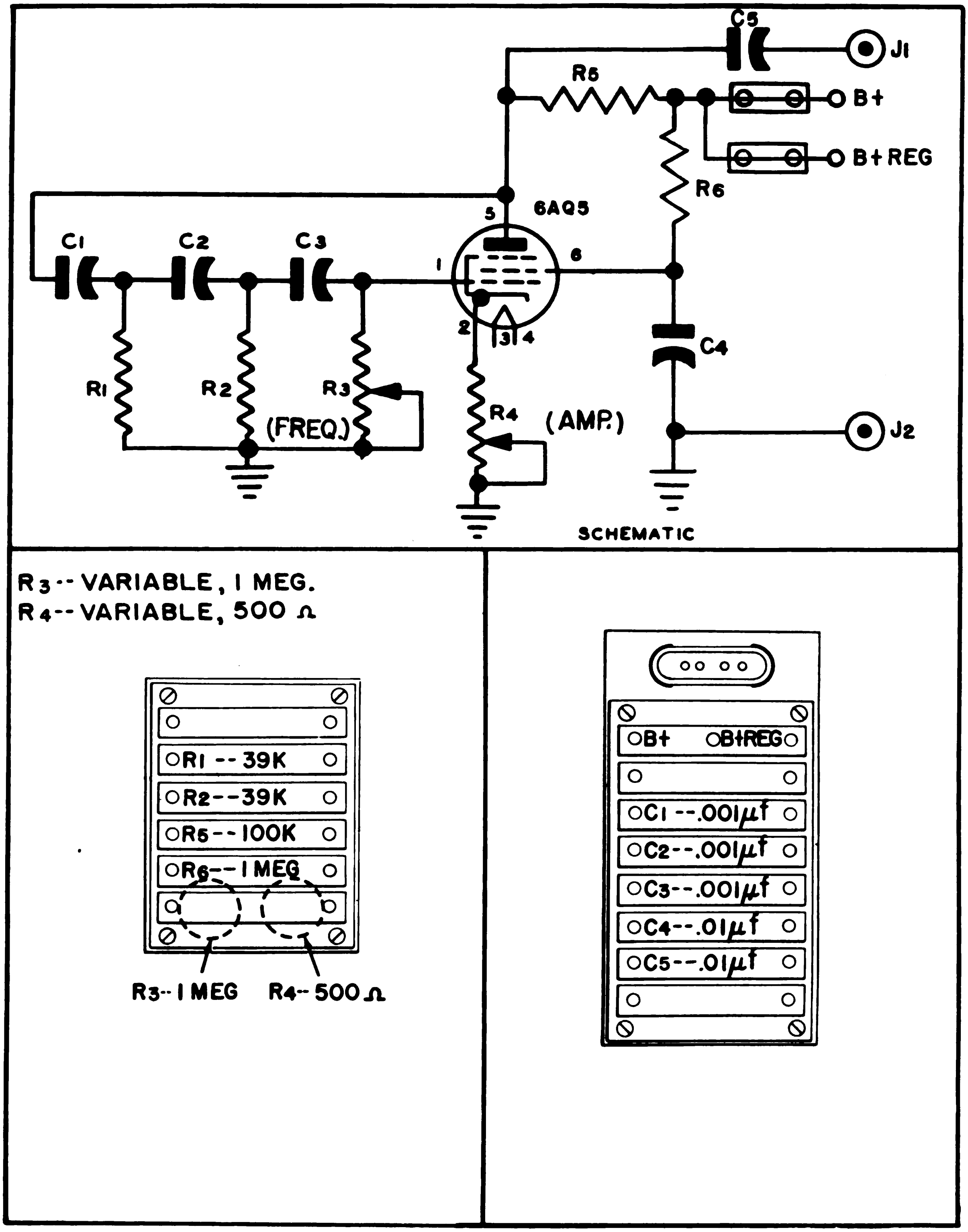
CONCLUSIONS

1. Why is a pentode tube, rather than a triode, used in this circuit?

Considerable gain is necessary in the circuit, in order to overcome the voltage loss arising in the three phase-shifting networks. The triode tube is incapable of producing enough gain to overcome this loss. A pentode tube, with its high amplification factor, must be used.

R-C OSCILLATOR VOLTAGE MEASUREMENTS AND WAVEFORMS

PLATE LOAD RESISTANCE (Ohms)	D-C PLATE (Volts)	D-C SCREEN (Volts)	A-F OUTPUT (Volts, r.m.s.)	A-F GRID (Volts, r.m.s.)	OUTPUT WAVEFORM
10,000	270	75	68	1.4	
47,000	160	40	60	0.9	
100,000	83	28	48	0.5	



Schematic Diagram of R-C Oscillator Chassis

LABORATORY PLAN No. 4

SUBJECT

The cathode follower.

OBJECTIVE

To supervise the testing and adjustment of the Cathode Follower Chassis.

MATERIAL REQUIRED

1. Cathode Follower Chassis.
2. Power Supply Chassis.
3. Five-inch oscilloscope with leads.
4. A-F oscillator with leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Square-Wave Generator Chassis.
8. Saw-tooth Generator Chassis.

INTRODUCTION

The cathode follower, whose circuit operation will be studied later in the course, is an invaluable tool during the earlier part of the course.

The procedure to be used and the precautions to be observed are the same as those for the square-wave generator and the saw-tooth generator. This EXPERIMENT, however, does not include a table of representative resistances and voltages. It is assumed that, by this time, the student has acquired sufficient familiarity with laboratory test procedure to be able to determine for himself what the correct voltages and resistances should be. Testing of the chassis with a voltmeter and an ohmmeter is to be carried out in the same manner in which it was performed in the EXPERIMENTS on the square-wave generator and the saw-tooth generator.

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit a Cathode Follower Chassis. Point out each physical part, and refer to it by the circuit symbol used in the schematic diagram.

2. Call attention to any improper practices still observed on the part of the students in testing and adjusting laboratory chassis.

Supervision

1. Continue the program of supervision begun with the square-wave generator and with the saw-tooth generator EXPERIMENTS. Demand increasing attention to detail, neatness, and intelligent planning.

2. In view of the omission of voltage and resistance tables, students will be expected to devise their own tests for determining proper connections in the chassis before connecting it to a power supply. Do not permit any team to connect its laboratory chassis until that team has devised and performed a set of satisfactory tests.

Adjustment

1. Conduct a demonstration of the results expected in the Operational Check section of the EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there, as was done in the case of the square-wave generator and of the saw-tooth generator.

2. Keep a close check on the waveforms being obtained. Demand increasing self-reliance upon the part of the students. Upon recognizing incorrect results, encourage the students to make preliminary checks to determine their cause. The students already have some knowledge of cathode followers, obtained from the phase splitter EXPERIMENT in the Basic Electronic Concepts and Circuits course.

3. Continue to insist upon accurate, carefully drawn waveforms.

CONCLUSIONS

The cathode follower is capable of functioning as a high-fidelity power amplifier. It may be used as an isolating circuit between timing circuits, such as the square-wave generator, and a stage requiring power to drive it.

EXPERIMENT No. 4

SUBJECT

The cathode follower.

OBJECTIVE

To test a cathode follower, and make sure that it is working properly; to learn how to connect the follower to the square-wave generator and the saw-tooth generator, which have been previously studied.

MATERIAL REQUIRED

1. Cathode Follower Chassis.
2. Power Supply Chassis..
3. Five-inch oscilloscope with leads.
4. A-F oscillator with leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Square-Wave Generator Chassis.
8. Saw-tooth Generator Chassis.

INSTRUCTIONS

In many cases, it is desirable to insert an isolating device between a source of signals and the following stage, to avoid loading the signal source. The cathode follower, which is admirably adapted to this purpose, will be used throughout the course.

> NOTE: The cathode follower may become overloaded, during the course of some EXPERIMENTS, by extremely high input voltages. This will result in distorted output wave-forms, especially flattened negative peaks.

PROCEDURE

1. Study the schematic diagram attached to this EXPERIMENT.

2. Insert the cathode follower chassis in the Laboratory Chassis Mounting Rack. *Do not insert the tube.*

Testing

1. Connect the power-supply unit for operation, and turn on the power.

2. Make voltage measurements in the same manner as specified in the EXPERIMENTS on the square-wave and the saw-tooth generators. Record the measurements in a suitable table, for use with the cathode follower. If discrepancies occur between the measured and the anticipated voltages, find and correct the error.

3. Submit to the instructor the tables you have prepared on resistance and voltage measurements, together with the measurements obtained, and get his approval before continuing.

Instructor's initials_______

Operational Check

1. With sine-wave input:

a. Insert the 6AB4 tube in the Cathode Follower Chassis.

b. Connect the scope to the output of the a-f oscillator, and observe the waveform at some frequency.

c. Connect the a-f oscillator to the INPUT jack of the cathode follower, and connect the scope to the OUTPUT jack of the cathode follower. Set R2 for maximum output.

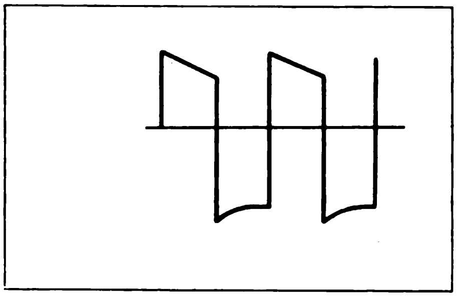
d. Observe the output waveform of the follower, and compare it with the input waveform obtained in b, above. If the two waveforms are not identical, except for amplitude, trouble exists, and must be located and removed.

e. With a vacuum-tube voltmeter, measure the r-m-s amplitude of the input and output signals, and calculate the gain of the cathode follower.

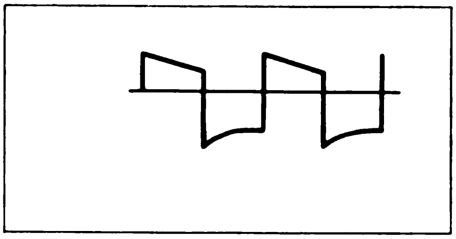
Gain_______

2. With square-wave input:

a. Disconnect the a-f oscillator from the input of the cathode follower, and connect the input of the follower to the OUTPUT jack of the square-wave generator by inserting the chassis immediately to the right.



Square-Wave Input



Square-Wave Output

b. Use the 1 meg resistor for R6 in the square-wave generator to produce symmetrical waves. (Refer to the EXPERIMENT on the square-wave generator.)

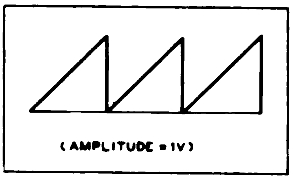
c. Observe, and draw to scale, in the space provided, the input and output waveforms of the cathode follower.

3. With saw-tooth input:

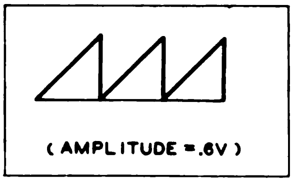
a. Connect the square-wave generator and the saw-tooth generator together and make adjustments to produce a good saw-tooth waveform.

b. Connect the output of the saw-tooth generator to the INPUT jack of the cathode follower.

c. Observe, and record to scale, in the spaces provided, the input and output waveforms of the cathode follower.



Saw-tooth Input



Saw-tooth Output

CONCLUSIONS

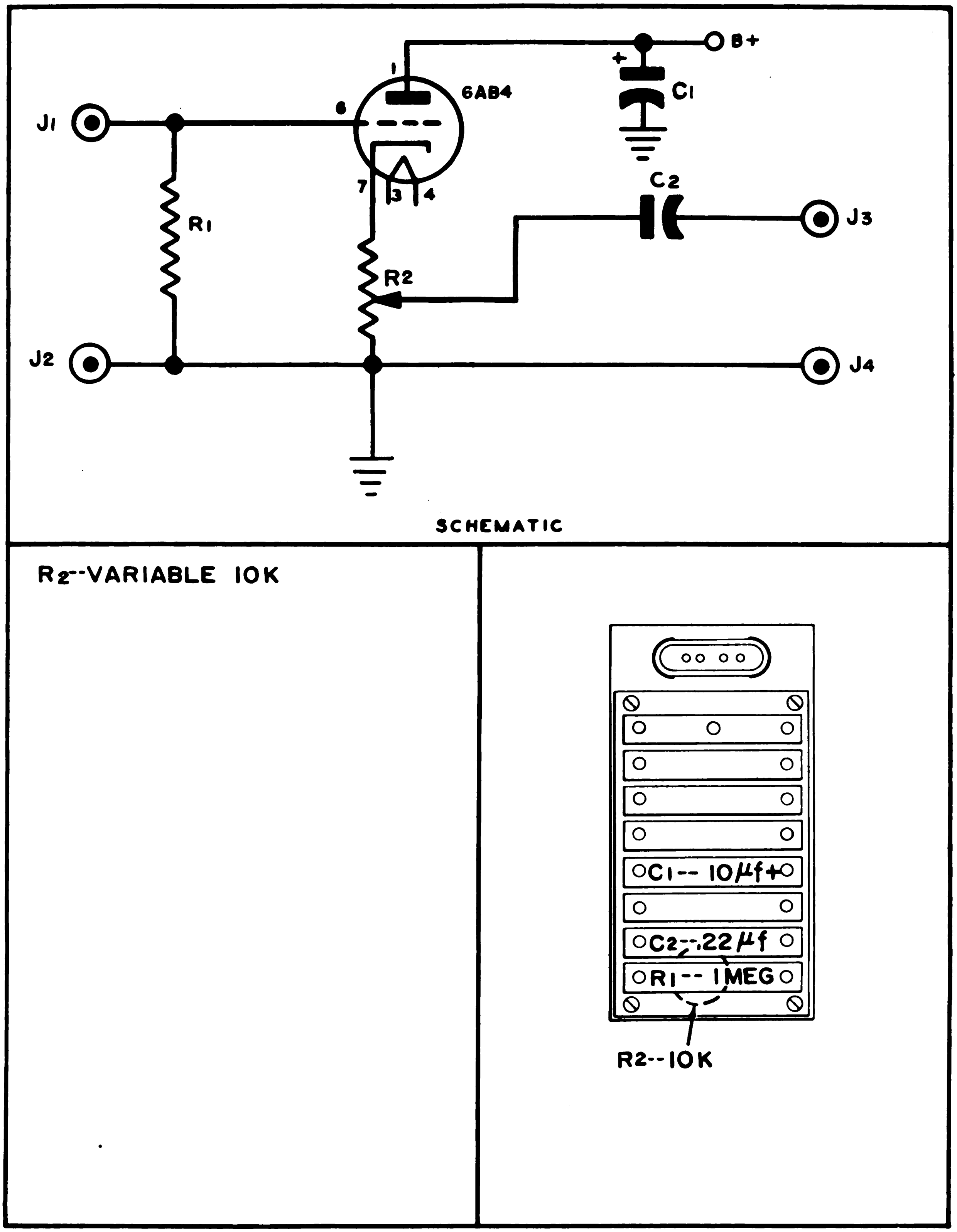
1. Why is it necessary to use a Cathode Follower?

The cathode follower is frequently used as an isolating device between a source of signals and the following stage, in order to avoid overloading the signal source and distorting its waveform.

2. If the peak amplitude of a sine-wave input to the cathode follower used in this EXPERIMENT is 100 volts, what will be the peak amplitude of the sine wave observed at the cathode-follower output jack? Why?

($E_{out} = E_{in} \times gain$)

3. Describe any difficulties encountered in obtaining proper operation of the equipment during this EXPERIMENT. What measures were taken to overcome these difficulties, and what were the results?



Schematic Diagram of Cathode Follower Chassis

LABORATORY PLAN No. 5

SUBJECT

The bias supply.

OBJECTIVE

To supervise the testing and operational check of a selenium rectifier bias supply.

To train the students in the precautions necessary for the trouble-shooting procedures used in dealing with such a power supply.

MATERIAL REQUIRED

1. Bias Supply Chassis.
2. Vacuum-tube voltmeter with leads.
3. Five-inch oscilloscope with leads.
4. A-F oscillator with leads.

INTRODUCTION

At various times throughout the course, it will become necessary to apply either a positive or a negative bias to different points of a circuit. The Bias Supply Chassis to be studied during this EXPERIMENT will serve as a source for these voltages.

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit a Bias Supply Chassis. Refer to each part by name, and indicate the symbols used to represent each on the schematic diagram.

2. Explain how the selenium rectifier is mounted on the chassis.

3. Explain how the electrolytic capacitors are mounted on the mounting strips, in order to make them mechanically rigid.

Supervision

1. Continue the program of supervision, as carried out during previous EXPERIMENTS.

2. Arrange to be present at the time when each successive team plugs in its Bias Supply Chassis for the first time. Demonstrate the proper method of:

   a. Applying the voltmeter to the output terminals before turning on the power, in order to detect immediately any incorrect operation.

   b. Testing for overheating capacitors, resistors, and selenium rectifiers, in order to detect improper operation before burnout can occur.

   c. Being on the alert for output leads not securely inserted in terminals.

Testing

1. Conduct a demonstration of the results expected in testing the chassis. Stress the fact that moderately high voltages are present in this chassis, and that care must be taken to prevent short circuits. Stress the location of output leads and of the control knobs associated with the positive bias and the negative bias.

2. Keep a constant check upon the tests as they proceed, being especially careful to locate the first signs of overloading in any of the equipments.

CONCLUSIONS

The selenium rectifier provides reliable bias voltage which can be varied, and which can be made either positive or negative.

EXPERIMENT No. 5

SUBJECT

The bias supply.

OBJECTIVE

To test a selenium-rectifier bias supply capable of supplying two bias voltages, as follows: 0—50 volts (approx.), positive with respect to the chassis; and 0—50 volts (approx.), negative with respect to the chassis.

MATERIAL REQUIRED

1. Bias Supply Chassis.
2. Vacuum-tube voltmeter with leads.
3. Five-inch oscilloscope with leads.
4. A-F oscillator with leads.

INSTRUCTIONS

Throughout the course, certain EXPERIMENTS will require positive or negative bias voltages. The chassis used in this EXPERIMENT will provide both positive and negative biases up to approximately 50 volts. It consists of a selenium rectifier, a section of R-C filter, and two potentiometers (each with a by-pass capacitor) for adjusting the positive and negative voltages to the exact values desired.

The electrolytic capacitors and the selenium rectifier are plainly marked at one terminal with the plus symbol (+). This symbol indicates that, under normal conditions, the terminal so marked is connected to a point of positive polarity. Similar plus signs are shown on the accompanying schematic diagram.

Connecting an electrolytic capacitor in reverse polarity will result in damage to the capacitor, and possibly to the rectifier. Connecting a rectifier in reverse polarity may result in damage to the rectifier itself, and also to the four electrolytic capacitors. *Do not fail to get the approval of your instructor before applying power to the chassis.*

Note particularly that *not all of the negative terminals* of the electrolytic capacitors are connected to the chassis. This is due to the fact that half of the supply output voltage is positive with respect to the chassis, while the other half is negative with respect to the chassis. This is often true of power supplies; therefore, the student should become accustomed to checking polarities of the various circuits as a matter of course, before connecting filter capacitors.

PROCEDURE

Testing

1. Insert the chassis in the rack.

2. Prepare a table of expected resistance values, and a table of expected voltage values, and provide a column in each table for corresponding resistance and voltage measurements to be made in this EXPERIMENT.

3. Make resistance and voltage measurements, as described in previous EXPERIMENTS, and record the measurements in the prepared tables.

4. Submit the completed tables to the instructor for approval.

Instructor's initials_______

NOTE: Remember that the resistance of an electrolytic capacitor is *not infinite.*

5. Measure and record the minimum and maximum bias voltages available at the two output jacks as follows:

Positive volts, min.______max.______d.c.
Negative volts, min.______max.______d.c.

6. Connect the scope to the positive output jack J1 of the chassis, and measure the peak ripple voltage appearing at that point, with the potentiometer adjusted to deliver maximum positive bias. This measurement should be made by comparing the ripple-voltage waveform with the output-voltage waveform of an a-f oscillator.

Ripple voltage, ______volts peak

7. Measure the positive d-c bias voltage obtained with maximum positive setting of the potentiometer R2.

Maximum d-c positive bias voltage,______volts

8. Using the same method given in step 6, above, measure the peak ripple voltage appearing between the negative output lead and chassis, with the potentiometer adjusted to deliver maximum negative bias.

Ripple voltage, ______ volts, peak

9. Measure the negative d-c bias voltage obtained with maximum negative setting of the potentiometer.

Maximum d-c negative bias voltage, _____ volts

10. Compute the percentage of peak ripple at the positive and at the negative output leads:

$$(\%\ \text{positive peak ripple} = \frac{\text{peak ripple voltage}}{\text{maximum DC voltage}} \times 100)$$

11. Obtain the instructor's approval of these results.

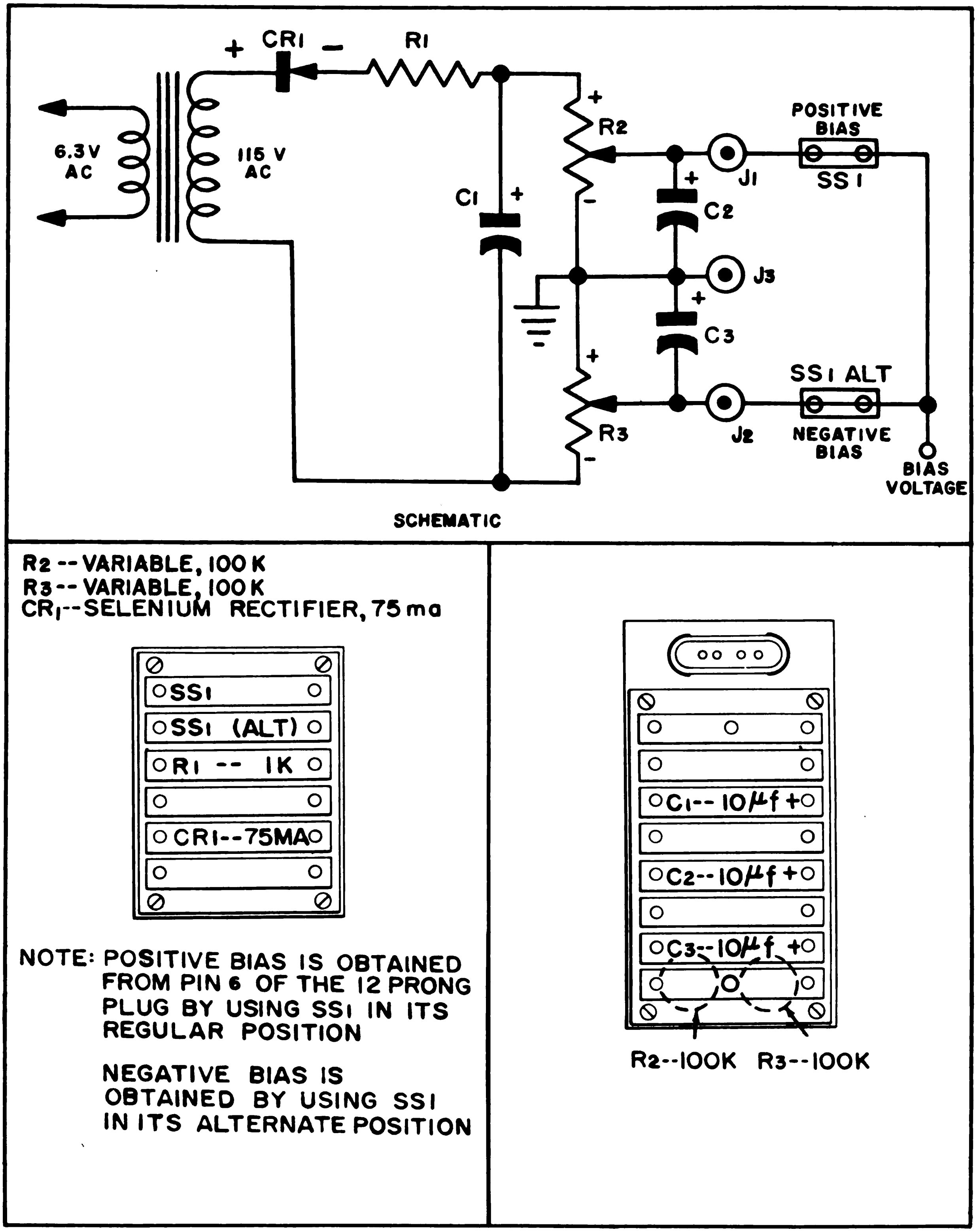
Instructor's initials_______

12. Measure the frequency of the output ripple by comparison with the output frequency of the a-f oscillator.

Ripple frequency_______cycles

CONCLUSIONS

Discuss the characteristics of the bias supply which was tested in this EXPERIMENT.



R2 -- VARIABLE, 100 K
R3 -- VARIABLE, 100 K
CR1--SELENIUM RECTIFIER, 75 ma

NOTE: POSITIVE BIAS IS OBTAINED FROM PIN 6 OF THE 12 PRONG PLUG BY USING SS1 IN ITS REGULAR POSITION

NEGATIVE BIAS IS OBTAINED BY USING SS1 IN ITS ALTERNATE POSITION

Schematic Diagram of Bias Supply Chassis

LABORATORY PLAN No. 6

SUBJECT

The testing of a mixer.

OBJECTIVE

To supervise the testing and adjustment of the Mixer Chassis in its various modes of operation.

MATERIAL REQUIRED

1. Mixer Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. A-F oscillator with leads.
5. Five-inch oscilloscope with leads.
6. Vacuum-tube voltmeter with leads.
7. Square Wave Generator Chassis.
8. Sawtooth Generator Chassis.

REFERENCES

Schematic diagram and layout in the accompanying EXPERIMENT.

INTRODUCTION

The circuit to be used in this EXPERIMENT has many uses. Therefore, it becomes a valuable tool in the laboratory; it will be used extensively in future EXPERIMENTS.

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit a Mixer Chassis to the class. Refer to each part by name, indicating the symbols used for each, as shown on the schematic diagram.

2. Explain how the electrolytic capacitor is mounted on the mounting strip, calling attention to both the electrical and mechanical considerations.

Supervision

Continue the program of supervision, as carried out during previous EXPERIMENTS.

Testing

Conduct a demonstration of the results expected in the Testing section of the EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there.

Operational Check

1. Perform a brief demonstration, showing how this Mixer Chassis can be used as an amplifier, as a plate-coupled mixer, as a cathode follower, and as a cathode-coupled mixer. Follow the steps given in the EXPERIMENT.

2. The waveforms obtained in this section of the EXPERIMENT are not familiar to the students. Keep a close check on their work as it progresses, and make sure they understand how the resultant waveforms are produced.

CONCLUSIONS

The Mixer Chassis studied in this EXPERIMENT is a versatile circuit. It has been used as a straightforward amplifier, as a cathode follower, as a plate-coupled mixer, and as a cathode-coupled mixer. Because of its many uses, this chassis will be frequently employed in future EXPERIMENTS. The student should become thoroughly familiar with the various circuit changes that must be made in order to convert this chassis for use as any of the four types of circuits named above.

EXPERIMENT No. 6

SUBJECT

The testing of a mixer.

OBJECTIVE

To test a mixer and insure that it is working properly.

MATERIAL REQUIRED

1. Mixer Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. A-F oscillator with leads.
5. Five-inch oscilloscope with leads.
6. Vacuum-tube voltmeter with leads.
7. Square Wave Generator Chassis.
8. Saw-tooth Generator Chassis.

REFERENCES

Schematic diagram and layout drawing accompanying this EXPERIMENT.

INSTRUCTIONS

The mixer to be tested in this EXPERIMENT has a variety of uses. It may be used as a conventional audio amplifier, a conventional cathode follower, or a mixer circuit to combine two incoming signals, with the output taken either from the plate or the cathode. The circuit, of course, has limitations as to maximum signal with which it may be driven without distortion, and as to maximum output. These limits are to be determined by the student, and recorded for future reference.

PROCEDURE

Testing

1. Remove SS1 ALT. and insert chassis in rack.
2. With the tube out of its socket, make the routine tests described in previous EXPERIMENTS. Record your results.
3. Have these results checked by the instructor.

Instructor's initials_______

Operational Check

1. Use the mixer as a straight amplifier.

a. Turn potentiometer R1 fully clockwise for maximum resistance and turn R2 fully counterclockwise.

b. Connect the audio oscillator between INPUT jack J1 and ground. (See figure 1.)

c. Adjust the a-f oscillator to a frequency of 1000 cycles.

d. Connect the oscilloscope to OUTPUT jack J4 and observe the waveform.

e. Adjust the output of the audio oscillator to the point where maximum distortionless output is obtained.

f. Measure the output voltage, using a vacuum-tube voltmeter.

Output ______ volts, r.m.s.

g. Without changing the oscillator adjustments, measure the input voltage to the mixer, and calculate the gain.

Input ______ volts, r.m.s.

Gain ______

2. Use the circuit as a plate-coupled mixer.

a. Connect the circuit as shown in the block diagram, figure 2.

b. Observe the resulting waveform.

c. Adjust the input potentiometers until a trapezoidal waveform is obtained. This waveform could be used to produce a saw-tooth shaped current in a coil.

d. Record this waveform at A in figure 5.

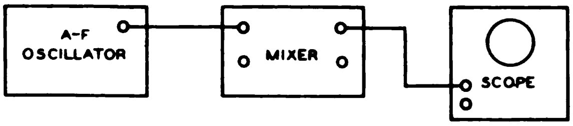
3. Use the circuit as a cathode follower.

a. Remove capacitor C1 from the circuit.

b. Replace resistor R4 with a shorting strip.

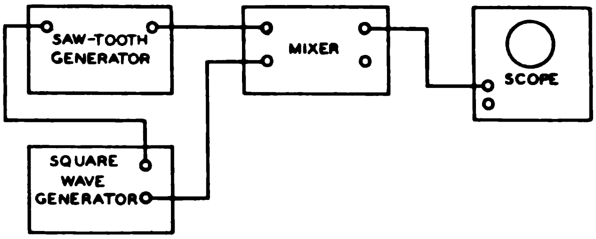
c. Remove SS1 and place a shorting strip in SS1 ALT.

d. Connect the equipment as shown in figure 3, and observe the output at OUTPUT jack J4 following the procedure given in step 1.



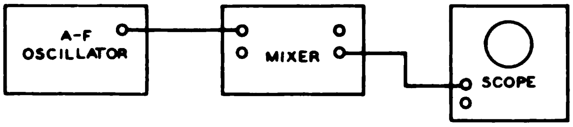
BLOCK DIAGRAM OF EQUIPMENT SET-UP FOR USE AS A STRAIGHT AMPLIFIER

Figure 1



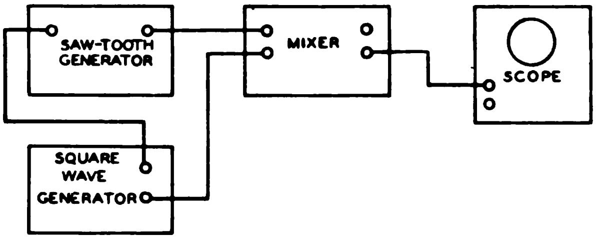
BLOCK DIAGRAM OF EQUIPMENT SET-UP FOR USE AS A PLATE COUPLED MIXER

Figure 2



BLOCK DIAGRAM OF EQUIPMENT SET-UP FOR USE AS A CATHODE FOLLOWER

Figure 3



BLOCK DIAGRAM OF EQUIPMENT SET-UP FOR USE AS A CATHODE-COUPLED MIXER

Figure 4

A

B

Figure 5

e. Record the values of maximum distortionless output, maximum input, and gain.

Output______volts Input______volts
Gain______

4. Use the circuit as a cathode-coupled mixer.

a. Replace the shorting strip at R4 with the 39K resistor.

b. Connect the circuit as shown in the block diagram, figure 4.

c. Adjust the input potentiometers until a trapezoidal waveform is observed on the oscilloscope.

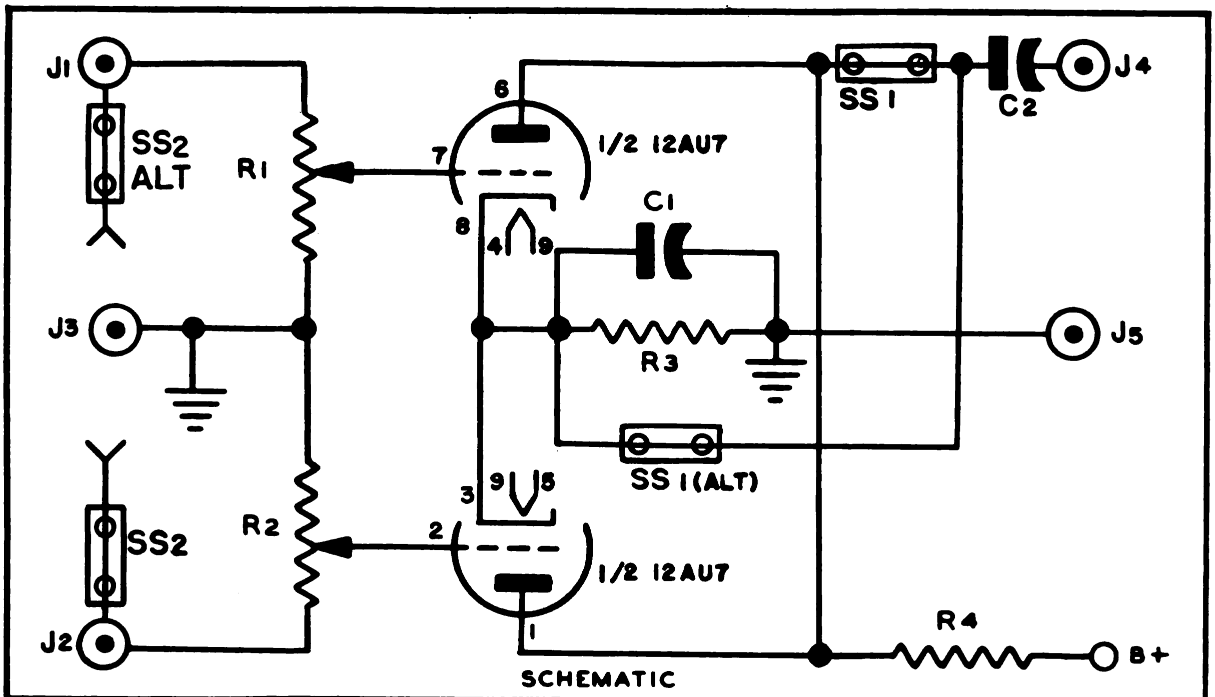
d. Record this waveform at B in figure 5.

CONCLUSIONS

1. Describe any difficulties encountered in obtaining proper operation of the equipment during the EXPERIMENT. What measures were taken to overcome these difficulties, and what were the results?

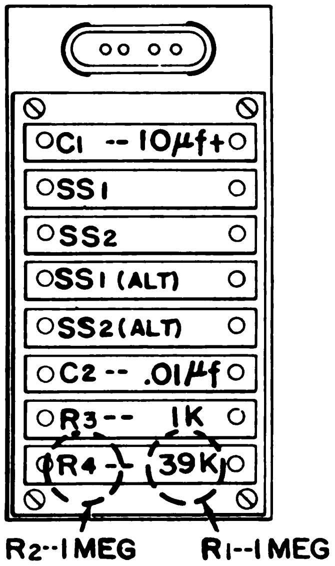
2. What difficulties would be encountered in trying to operate the circuit as a plate-coupled mixer with the cathode by-pass capacitor removed? Why?

The gain of the circuit would be reduced considerably, because the tube would be improperly biased. In the event that the two incoming signals are of extremely different amplitude, the larger would saturate the circuit during positive peaks, and the smaller signal is biased past cutoff during the positive peaks mentioned above, since most of the tube current developed flows through the tube upon which the larger signal is impressed.



R1--VARIABLE, 1 MEG
R2--VARIABLE, 1 MEG

NOTE: AN OUTPUT MAY BE OBTAINED FROM THE CATHODE BY USING SS-1 IN ITS ALTERNATE POSITION.



Schematic Diagram of Mixer Chassis

LABORATORY PLAN No. 7

SUBJECT

The differentiator circuit.

OBJECTIVE

To supervise the testing of the differentiator circuit; to assist the students in their analysis of the operation of the circuit.

MATERIAL REQUIRED

1. Differentiator-Integrator Chassis.
2. Power Supply Chassis.
3. Laboratory Chassis Mounting Rack.
4. Square Wave Generator Chassis.
5. Saw-tooth Generator Chassis.
6. Five-inch oscilloscope with leads.
7. A-F oscillator with leads.

INTRODUCTION

The chassis to be used during this laboratory session can be made to function as either a differentiator or an integrator, by use of the proper circuit arrangement. For this EXPERIMENT, the circuit should be connected as a differentiator.

SUBJECT MATERIAL

Introductory Demonstration

1. Exhibit a Differentiator-Integrator Chassis to the class. Point out each part, referring to it by name and proper symbol, as used in the schematic.

2. Explain how the circuit is to be connected for use as a differentiator.

Supervision

Have the students check the Square Wave Generator Chassis, to insure that the proper parts are mounted. Refer to the EXPERIMENT for correct values.

Operational Check

1. Conduct a brief demonstration of one or two of the operations called for in the EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there.

2. Keep a close check on the waveforms being obtained. Help the students recognize incorrect results and determine their causes.

CONCLUSIONS

The differentiator is used to modify the shape of an incoming waveform. Through its action, a broad square wave can be made into two sharp pulses, or the phase of a sine wave can be changed. Generally, the circuit accentuates any sudden change in the shape of the incoming signal. In many radar and television circuits, this function is valuable.

EXPERIMENT No. 7

SUBJECT

The differentiator circuit.

OBJECTIVE

To show the waveform obtained from a differentiator circuit when a square wave, a saw-tooth wave, and a sine wave are separately applied.

MATERIAL REQUIRED

1. Differentiator-Integrator Chassis.
2. Power Supply Chassis.
3. Laboratory Chassis Mounting Rack.
4. Square Wave Generator Chassis.
5. Saw-tooth Generator Chassis.
6. Five-inch oscilloscope with leads.
7. A-F oscillator with leads.

INSTRUCTIONS

The Differentiator-Integrator Chassis contains a resistor and a capacitor. The accompanying schematic diagram and layout drawing show how the chassis is wired, page 177.

PROCEDURE

1. Put in plug-in parts as shown in the schematic.

2. Check the Square Wave Generator Chassis to make certain that the parts listed below are as indicated:

R1 and R2—22,000 ohms.
R3 and R4—2.2 megohms.
C1 and C2—.001 µf.

Differentiation of a Square Wave

Long Time Constant

1. Connect the scope to the output of the square-wave generator.

2. At A in figure 1, draw to scale one cycle of the observed waveform. Measure the frequency of the square wave by comparison with the output of the a-f oscillator.* Record the square-wave frequency and period.

Frequency_____cycles
Period_____µsec.

3. In the differentiator, insert the one-megohm resistor at R1, and a .1-µf. capacitor at C1.

4. Connect the output of the square-wave generator to the input of the differentiator, and connect the scope to the OUTPUT No. 1 jack.

5. At B in figure 1, draw to scale the observed waveform.

Medium Time Constant

1. In the differentiator, leave the one-megohm resistor at R1, and insert the .01-µf. capacitor at C1.

2. At C in figure 1, record the observed waveform.

Short Time Constant

1. In the differentiator, leave the one-megohm resistor at R1, and insert the 100-µµf. capacitor at C1.

2. At D in figure 1, record the observed waveform.

Differentiation of a Sawtooth Wave

Long Time Constant

1. Connect the saw-tooth generator between the square-wave generator and the differentiator.

2. In the differentiator, insert the one-megohm resistor at R1, and a .1-µf capacitor at C1.

3. In the saw-tooth generator, insert a .1-µf. capacitor at C1.

4. Connect the scope to OUTPUT jack J3 of the saw-tooth generator, and change the value of R6 in the square-wave generator until the saw-tooth waveforms join at the bottom, at a sharp angle.

5. Adjust the saw-tooth-generator potentiometer until the long, rising portion of the saw-tooth waveform is as straight as possible.

6. Obtain the instructor's approval of these adjustments.

Instructor's Initials_______

7. At E in figure 1, record the observed waveform.

8. Measure the frequency, and compute the period of the saw-tooth waveform.

Frequency_____cycles
Period_____µsec.

9. Connect the scope to the OUTPUT jack, J3, of the differentiator.

10. At F in figure 1, record the observed waveform.

Medium Time Constant

1. Change the differentiator capacitor to .01 µf.

2. At G in figure 1, record the observed waveform.

Short Time Constant

1. Change the differentiator capacitor to 100 µµf.

2. At H in figure 1, record the observed waveform.

DIFFERENTIATOR INPUT WAVEFORM		
SQUARE WAVE	*SAW-TOOTH WAVE*	*SINE WAVE*
A PERIOD µSEC	E PERIOD µSEC	I PERIOD µSEC

DIFFERENTIATED WAVEFORM		
SQUARE WAVE INPUT	*SAW-TOOTH WAVE INPUT*	*SINE WAVE INPUT*
B LONG TIME CONSTANT TIME CONSTANT µSEC	F LONG TIME CONSTANT TIME CONSTANT µSEC	J LONG TIME CONSTANT TIME CONSTANT µSEC
C MEDIUM TIME CONSTANT TIME CONSTANT µSEC	G MEDIUM TIME CONSTANT TIME CONSTANT µSEC	K MEDIUM TIME CONSTANT TIME CONSTANT µSEC
D SHORT TIME CONSTANT TIME CONSTANT µSEC	H SHORT TIME CONSTANT TIME CONSTANT µSEC	L SHORT TIME CONSTANT TIME CONSTANT µSEC

Figure 1. Waveforms, Differentiation with Various Time Constants

Differentiation of a Sine Wave

1. Disconnect the differentiator from the sawtooth generator and insert the .1-μf capacitor for C1.

2. Connect the a-f oscillator to the input of the differentiator. Adjust the oscillator to the frequency of the square-wave-generator output.

3. Connect the scope to the a-f oscillator output. At I in figure 1, record the observed waveform.

4. Connect the scope to the differentiator output. At J in figure 1, record the observed waveform.

5. In the differentiator, replace the .1-μf. capacitor at C with a .01-μf. capacitor.

6. With the scope connected to the differentiator output, record the observed waveform at K in figure 1.

7. Replace the .01-μf. capacitor with a .001-μf. capacitor.

8. With the scope connected to the differentiator output, record the observed waveform at L in figure 1.

CONCLUSIONS

1. What is a differentiating circuit?

A differentiating circuit is a series R-C circuit whose time constant is of the order of one-tenth of the pulse width of the incoming wave, and whose output is taken from across the resistor. The output is distorted at a rate proportional to the change in slope of the incoming signal.

2. In a differentiating circuit, what is the required relationship between the product of the circuit resistance and capacitance and the width of the pulse being differentiated?

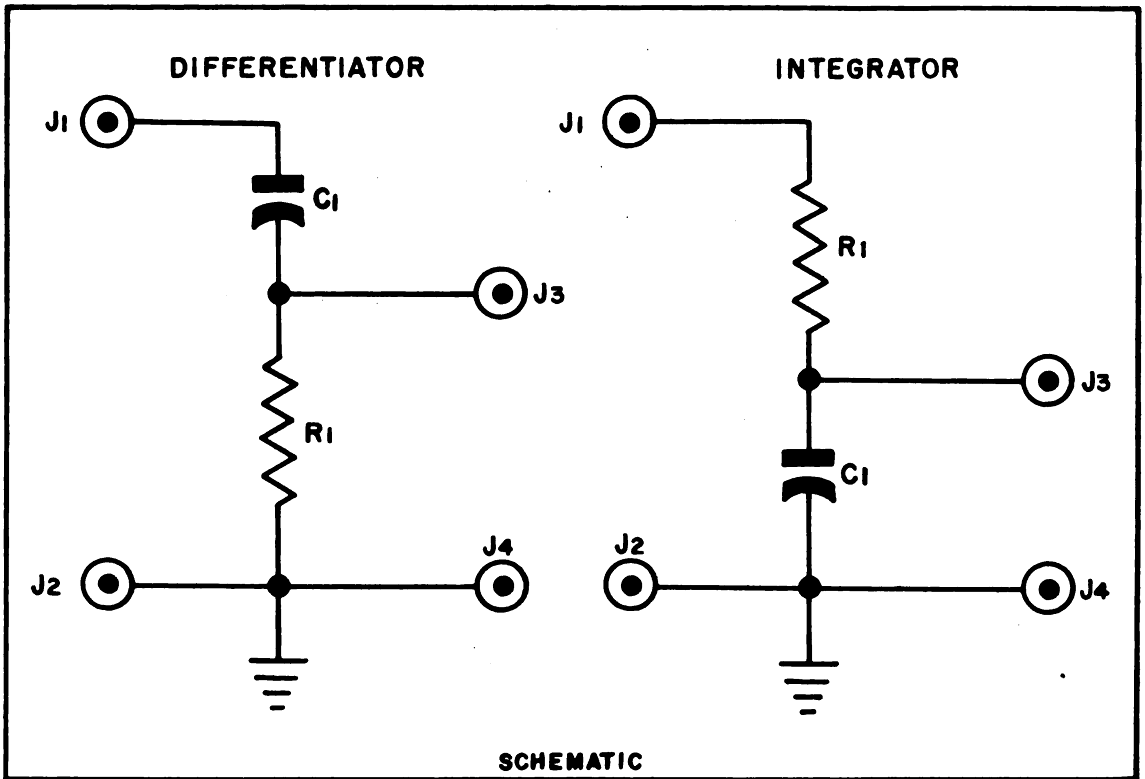
To be acceptable, the RC time constant must not be greater than one-fifth of the width of the pulse.

The maximum RC time constant that is usually employed, however, is one-tenth of the width of the pulse.

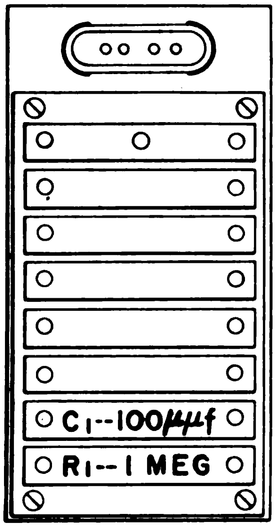
RC time constants shorter than one-tenth of the pulse width will result in narrower differentiated pulses, which are often desirable. Care must be taken, however, to make sure that enough resistance remains in the circuit so that the output-pulse amplitude does not fall off excessively. There must also be enough resistance remaining in the circuit so that it will not load the voltage source enough to distort the input waveform.

3. Name several uses for a differentiating circuit in electronic work.

The differentiating circuit is useful in producing waveforms suitable for timing pulses, marker pulses, and accurate trigger pulses for other circuits.



NOTE: POSITIONS SHOWN FOR R_1 AND C_1 ARE FOR DIFFERENTIATION. REVERSE R_1 AND C_1 FOR INTEGRATION.



Schematic Diagram of Differentiator-Integrator Chassis

LABORATORY PLAN No. 8

SUBJECT

The integrator circuit.

OBJECTIVE

To assist the students in their analysis of the operation of the integrator circuit.

MATERIAL REQUIRED

1. Differentiator-Integrator Chassis.
2. Laboratory Chassis Mounting Rack.
3. Square Wave Generator Chassis.
4. Saw-tooth Generator Chassis.
5. Power Supply Chassis.
6. Five-inch oscilloscope with leads.
7. AF signal generator.

INTRODUCTION

The Differentiator-Integrator Chassis was analyzed in the previous EXPERIMENT. However, the circuit elements must be rearranged before the circuit can perform as an integrator. The schematic diagram in EXPERIMENT No. 8 indicates the changes that must be made before the student can analyze the circuit.

SUBJECT MATERIAL

Supervision

1. Call to the attention of the class any inaccurately produced waveforms, any inaccurately recorded waveforms, and any other discrepancies that occurred in the previous EXPERIMENT.

2. Point out to the class the changes that must be made to convert the differentiating circuit to the integrating circuit.

3. Conduct a brief demonstration of one or two of the operations called for in the EXPERIMENT, indicating the results to be expected. Refer to the EXPERIMENT, and follow the steps given there.

4. Keep a close check on the waveforms obtained.

Point out that it is very important to record these waveforms accurately, for future reference.

CONCLUSIONS

The only physical difference between the integrator circuit and the differentiator circuit is that the output of the integrator is taken from across the capacitor in a series R-C circuit, while the output of the differentiator is taken from across the resistor in a series R-C circuit. Electrically, the difference between the two circuits lies in the values of the time constants. In the integrator circuit, the RC time constant is about ten times the period of the incoming signal pulses; in the differentiator circuit, the RC time constant is about one-tenth of the period of the incoming signal pulses.

EXPERIMENT No. 8

SUBJECT

The integrator circuit.

OBJECTIVE

To show the waveforms obtained by integrating square waves, saw-tooth waves, and sine waves; and to show the effect of the time constant upon the integrated output waveforms.

MATERIAL REQUIRED

1. Differentiator-Integrator Chassis.
2. Laboratory Chassis Mounting Rack.
3. Square Wave Generator Chassis.
4. Saw-tooth Generator Chassis.
5. Power Supply Chassis.
6. Five-inch oscilloscope with leads.
7. AF signal generator.

INSTRUCTIONS

The integrator circuit is identical with the differentiator circuit except that the former has a long time constant, and its output is taken from across the capacitor instead of across the resistor.

PROCEDURE

Integration of a Square Wave

Long Time Constant

1. Connect the scope to the output of the square-wave generator, and adjust the generator for a symmetrical waveform.

2. At A in figure 1, draw to scale one cycle of the observed waveform. Measure the frequency of this wave by comparison with the output of the audio-frequency oscillator. Record the frequency and the corresponding period.

Frequency______cycles
period______μsec.

3. On the Differentiator-Integrator Chassis, change R1 to 2.2 megohms; change C1 to .01-μf. capacitor.

4. Connect the output of the square-wave generator to the input of the integrator, and connect the scope to the OUTPUT jack J3 of the Differentiator-Integrator Chassis. At B in figure 1, draw to scale the observed waveform.

Medium Time Constant

1. Change R1 to 100,000 ohms, and leave the .01-μf. capacitor at C1.

2. At C in figure 1, record the observed waveform.

Short Time Constant

1. Change R1 to one megohm and C1 to 100 μμf.

2. At D in figure 1, record the observed waveform.

Integration of a Saw-tooth Wave

Long Time Constant

1. Connect the scope to the output of the square-wave generator, and adjust the generator for a symmetrical waveform.

2. Connect the output of the square-wave generator to the input of the saw-tooth generator, and connect the scope to the output of the saw-tooth generator.

3. Change the value of R6 of the square-wave generator until the saw-tooth waveforms join, at a sharp angle, at the bottom.

4. Adjust the potentiometer of the saw-tooth generator until the long, rising portion of the saw-tooth is as straight as possible. Obtain the instructor's approval of these adjustments.

Instructor's initials______

5. On the Differentiator-Integrator Chassis, change C1 to .01-μf. (R1 = 1 meg).

6. Connect the output of the saw-tooth generator to the input of the integrator.

7. Leave the scope connected to the output of the sawtooth generator, and record the observed waveform at E in figure 1.

8. Measure the frequency of this wave, and compute its period.

Frequency______cycles
Period______μsec.

9. Connect the scope to OUTPUT jack J3 of the integrator, and record the observed waveform at F in figure 1.

Medium Time Constant

1. Change R1 on the Differentiator-Integrator Chassis to 100,000 ohms, and leave the .01-μf. capacitor at C1.

2. Record the observed waveform at G in figure 1.

Short Time Constant

1. Change R1 to one megohm, and the capacitor at C1 to 100 μμf.

2. Record the observed waveform at H in figure 1.

Integration of a Sine Wave

1. Connect the audio-frequency oscillator to the input of the integrator.

2. Connect the scope to the output of the audio-frequency oscillator, and record the observed waveform at I in figure 1.

3. Connect the scope to the OUTPUT jack J3 of the integrator, and record the observed waveform at J in figure 1.

4. Observe the output waveforms with R1 in the integrator changed to 100,000 ohms, then to 10,000 ohms.

5. At K and L of figure 1, record the waveforms obtained with the 100,000-ohm and 10,000-ohm resistors, respectively.

CONCLUSIONS

1. Supply the correct information in the following:

a. An integrator circuit must have a time constant that is _____ in comparison with the time required for one pulse of the incoming wave (preferably _______ as long).

b. The output is taken across _____ (R or C).

c. The integration of a square wave produces a waveform of _______ shape.

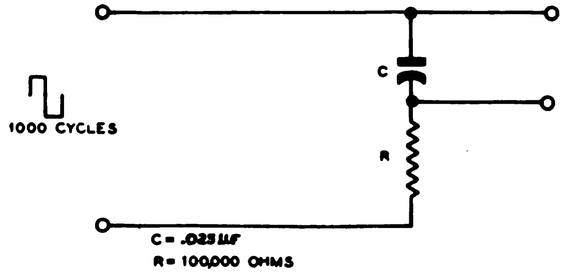
INTEGRATOR INPUT WAVEFORM

SQUARE WAVE	SAW-TOOTH WAVE	SINE WAVE
A PERIOD µSEC	E PERIOD µSEC	I PERIOD µSEC

INTEGRATED WAVEFORM

SQUARE WAVE INPUT	SAW-TOOTH WAVE INPUT	SINE WAVE INPUT
B LONG TIME CONSTANT TIME CONSTANT µSEC	F LONG TIME CONSTANT TIME CONSTANT µSEC	J LONG TIME CONSTANT TIME CONSTANT µSEC
C MEDIUM TIME CONSTANT TIME CONSTANT µSEC	G MEDIUM TIME CONSTANT TIME CONSTANT µSEC	K MEDIUM TIME CONSTANT TIME CONSTANT µSEC
D SHORT TIME CONSTANT TIME CONSTANT µSEC	H SHORT TIME CONSTANT TIME CONSTANT µSEC	L SHORT TIME CONSTANT TIME CONSTANT µSEC

Figure 1. Waveforms, Integration with Various Time Constants



Integrating Circuit with a Time Constant of 5000 Microseconds

d. The integration of a saw-tooth wave produces a waveform of parabolic shape.

e. The integration of a sine wave produces a waveform of sine-wave shape.

2. Draw an integrating circuit suitable for changing symmetrical square waves into triangular waves having nearly linear sides. Let the square wave have a frequency of 1000 cycles per second.

The period of a 1000-cycle wave = 1000 μsec.

The time occupied by one of the symmetrical pulses of this square wave is one-half of 1000, or 500 μsec:

While acceptable integration can be obtained by making the RC time constant equal to 5 times the pulse width, really linear triangular waves require a time constant of 10 times the pulse width. In this case, $RC = 10 \times 500 = 5000$ μsec.

Assume any suitably large value of R, so that the circuit will not load the preceding circuit. For example, let R = 1 meg.

Substituting:

$RC = 5000$ μsec.

$10^6 \times C = 5000$ μsec.

Solving for C:

$C = 5000 \times 10^{-6} / 10^6 = .005$ μf.

(RC, for such calculations, is expressed as R in megohms and C in μμf., giving the time constant in μsec.)

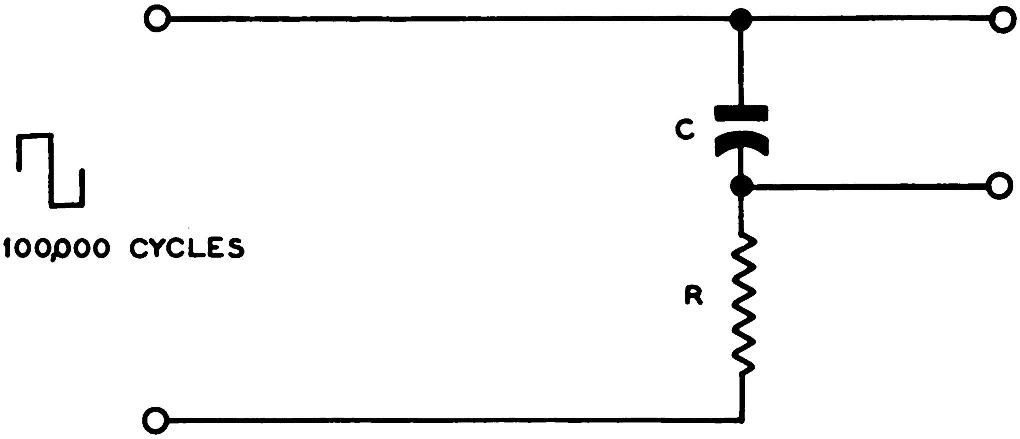
3. Draw a circuit suitable for producing acceptable (but by no means perfect) integration of a symmetrical square wave having a frequency of 100 kc.

The period of a 100-kc. wave is $\frac{10^6}{10^5} = 10$ μsec.

The time occupied by one-half of this square wave is 10/2 or 5 μsec.

For acceptable (although not perfect) integration, the integrator time constant must not be shorter than 5×5 μsec., or 25 μsec.

In choosing values of R and C, remember that R must be made large enough (if possible) to avoid loading the preceding stage. If R = 100 k then C = 250 mmf.



Integrating Circuit with a Time Constant of 25 Microseconds

LABORATORY PLAN No. 9

SUBJECT

The testing of the Series Diode Limiter Chassis.

OBJECTIVE

To supervise the testing of a Series Diode Limiter Chassis, to be used in the following EXPERIMENTS.

MATERIAL REQUIRED

1. Series Diode Limiter Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. Vacuum-tube voltmeter with leads.

INTRODUCTION

The Series Diode Limiter Chassis to be used during this EXPERIMENT employs no B+ voltage. Circuit testing will, therefore, be limited to a measurement of the heater voltage, and to the routine resistance measurements at various points in the circuit.

SUBJECT MATERIAL

Introductory Demonstration

Exhibit a Series Diode Limiter Chassis. Refer to each part by name, indicating the symbol by which it is designated in the schematic diagram.

Supervision

Proceed as in previous EXPERIMENTS.

CONCLUSIONS

Limiters are useful in wave-shaping circuits where it is desirable to square off the extremities of the applied waveform, or to remove either the positive or the negative portions.

EXPERIMENT No. 9

SUBJECT

Testing of a series diode limiter.

OBJECTIVE

To test a series diode limiter.

MATERIAL REQUIRED

1. Series Diode Limiter Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

In this and the next few EXPERIMENTS, you will investigate the operation, application, and trouble shooting of three types of limiters, the first of which is the series diode limiter. As is the case with most of the laboratory chassis, the Series Diode Limiter Chassis will be used from time to time throughout the course in conjunction with other chassis. It is of great importance, therefore, that it be given a rigid inspection, to make sure that it will not become the source of future trouble.

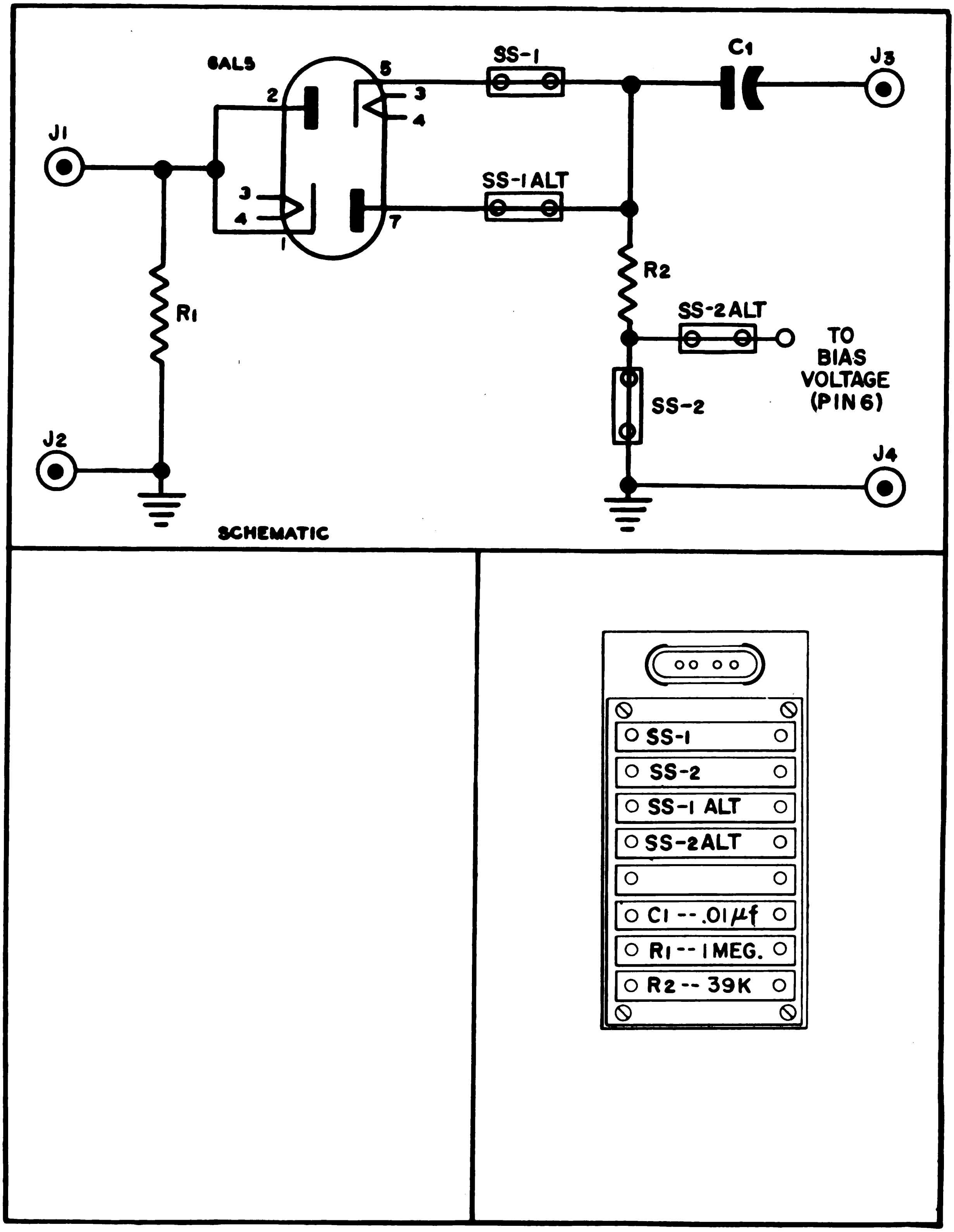
PROCEDURE

Testing

1. Obtain the material listed in 1 to 4 of MATERIAL REQUIRED.

2. With the tube out of its socket, make the routine tests described in previous EXPERIMENTS. Obtain the instructor's approval of your results.

Instructor's initials________



Schematic Diagram of Series Diode Limiter Chassis

LABORATORY PLAN No. 10

SUBJECT

The testing of a Parallel Diode Limiter Chassis.

OBJECTIVE

To supervise the testing of a Parallel Diode Limiter Chassis, for use in the following EXPERIMENT.

MATERIAL REQUIRED

1. Parallel Diode Limiter Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. Vacuum-tube voltmeter with leads.

INTRODUCTION

The Parallel Diode Limiter Chassis to be tested in this EXPERIMENT will be used in a future EXPERIMENT, where its circuit operation will be studied. The student should note that a double-diode tube is used, and that it will not operate properly if the plates and cathodes are cross-connected (that is, if the plate of one section is connected so as to operate against the cathode of the other section).

SUBJECT MATERIAL

Introductory Demonstration

Display the Parallel Diode Limiter Chassis. Refer to each part by name, indicating the symbol by which it is designated in the schematic diagram.

Supervision

Proceed as in previous EXPERIMENTS.

Testing

Insist upon high-grade workmanship and intelligent layout and testing of the chassis.

CONCLUSIONS

In limiting, a portion of a wave is flattened off or eliminated to some predetermined level, irrespective of the amplitude of the input signal in excess of this limiting level.

EXPERIMENT No. 10

SUBJECT

The testing of a parallel diode limiter.

OBJECTIVE

To test a parallel diode limiter.

MATERIAL REQUIRED

1. Parallel Diode Limiter Chassis.
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

Same as those in EXPERIMENT No. 9.

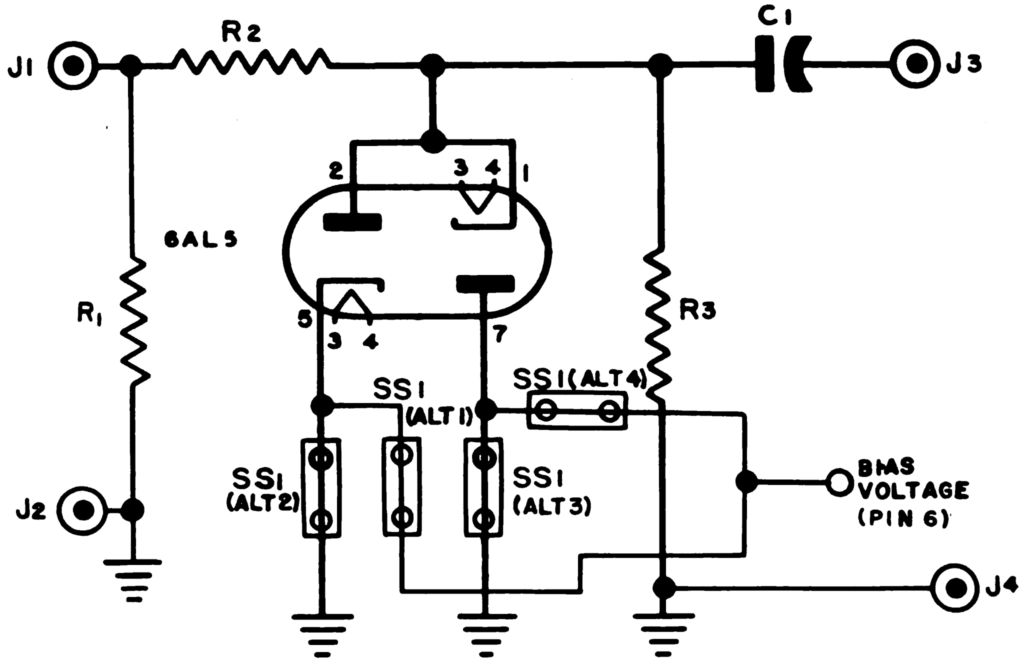
PROCEDURE

Testing

1. Obtain the material listed in 1, 2, 3, and 4 of MATERIAL REQUIRED.

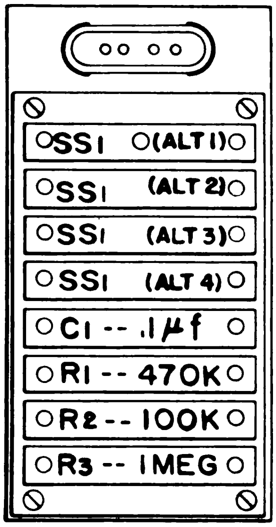
2. With the tube out of its socket, make the required routine tests. Obtain the instructor's approval of your results.

Instructor's initials______



SCHEMATIC

NOTE: SS1 MAY BE USED IN ANY ONE OF FOUR POSITIONS AS SHOWN.



Schematic Diagram of Parallel Diode Limiter Chassis

LABORATORY PLAN No. 11

SUBJECT

The series diode limiter.

OBJECTIVE

To help the students understand the circuit operation in this type of limiting.

MATERIAL REQUIRED

1. Series Diode Limiter Chassis.
2. Laboratory Chassis Mounting Rack.
3. R-C Oscillator Chassis.
4. Cathode Follower Chassis.
5. Square Wave Generator Chassis.
6. Differentiator-Integrator Chassis.
7. Bias Supply Chassis.
8. Power Supply Chassis.
9. Five-inch oscilloscope with leads.
10. Vacuum-tube voltmeter with leads.

INTRODUCTION

The series diode limiter is widely used in radar when it is necessary to remove part of a waveform without changing the shape of the remaining portion of the waveform. Either the positive or negative lobe may be removed.

SUBJECT MATERIAL

From this point in the course, the practice of subdividing the SUBJECT MATERIAL into distinct sections will be eliminated from LABORATORY PLANS. However, it is believed that the policy used in previous EXPERIMENTS should be continued to the end of the course. It is only being omitted to avoid monotony in reading on the instructor's part. Also, it is believed that, by this time, the instructor should be familiar enough with the general procedure of the LABORATORY PLANS to make continued subdivision unnecessary.

1. Conduct a brief demonstartion, indicating the results expected of the students. Refer to the EXPERIMENT, and follow the steps given there.

2. Insist that the waveforms produced and the voltages measured be neatly and accurately drawn and recorded.

CONCLUSIONS

The series diode limiter is widely used in radar circuits to clip off portions of a waveform without distorting the remaining part.

EXPERIMENT No. 11

SUBJECT

The series diode limiter.

OBJECTIVE

To study the circuits used in this type of limiter; to show how either positive or negative alternations of a wave can be eliminated; to develop a set of rules to be used as a guide in adjusting bias voltage to obtain the kind and degree of limiting desired; and to show the effect of limiting resistance upon the output waveform.

MATERIAL REQUIRED

1. Laboratory Chassis Mounting Rack.
2. Series Diode Limiter Chassis.
3. R-C Oscillator Chassis.
4. Cathode Follower Chassis.
5. Square Wave Generator Chassis.
6. Differentiator Chassis.
7. Bias Supply Chassis.
8. Power Supply Chassis.
9. Five-inch oscilloscope with leads.
10. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

The series diode limiter is the first of the three types of limiters that will be studied. All these circuits are widely used in radar and other systems when it is necessary to remove part of a waveform without changing the shape of the rest of the waveform.

One of the units employed in this EXPERIMENT is the Bias Supply Chassis. This chassis will furnish positive and negative potentials which may be as high as 50 volts each (depending upon the setting of the potentiometers).

PROCEDURE

Negative-Lobe Limiting

1. Connect together the R-C oscillator, the cathode follower, the series diode limiter, power supply and the scope, as shown in figure 1.

2. At A in figure 2, record the waveform observed at the input of the limiter. Reduce the output of the oscillator until there is no distortion.

3. At B in figure 2, record the waveform observed at the OUTPUT jack J3 of the limiter with SS-1 and SS-2 in normal position.

Positive-Lobe Limiting

1. Connect the scope lead to OUTPUT jack J3 of the limiter with SS-1 in alternate position. The lower section of the double diode will now be in use, instead of the upper section employed for negative-lobe limiting.

2. Note how the connections of the lower section differ from those of the upper section. Describe this difference.

3. At C in figure 2, record the waveform observed at the input of the limiter.

4. At D in figure 2, record the waveform observed at OUTPUT jack J3 of the limiter.

Effect of Bias

Positive Bias on Cathode of Upper Diode Section (pins 2 and 5)

1. Place SS-1 in its normal position and SS-2 in its alternate position. Connect SS-1 of the Bias Supply Chassis in its normal position. This places the variable positive bias between the bottom of R2 and ground. This bias, which can be varied by turning the potentiometer on the Bias Supply Chassis, is impressed upon the cathode of the upper diode section (see A of figure 3).

2. Vary the positive bias-supply potentiometer over its entire range. Note the changes that occur in the waveform observed at OUTPUT jack, J3.

3. At A in figure 3, record the trace obtained with the bias potentiometer set for 5 volts bias.

Negative Bias on Cathode of Upper Diode Section (pins 2 and 5)

1. Connect SS-1 of the Bias Supply Chassis in its alternate position. This places a negative bias on the cathode of the upper diode section (see B in figure 3).

2. Vary the negative bias-supply potentiometer over its range, and note the changes that occur in the waveform observed at OUTPUT jack, J3.

3. At B in figure 3, record the trace obtained with the potentiometer set for −50 volts bias.

Positive Bias on Plate of Lower Diode Section (pins 1 and 7)

1. With SS-1 and SS-2 of the limiter in alternate positions, place SS-1 of the Bias Supply Chassis in normal position. This places a variable

positive bias upon the plate of the lower diode section.

2. Vary the positive bias-supply potentiometer over its range, and note the change in waveform observed at OUTPUT jack, J3.

3. At C in figure 3, record the trace obtained with the potentiometer set for +50 volts bias.

Negative Bias on Plate of Lower Diode Section (pins 1 and 7)

1. Connect SS-1 of the Bias Supply Chassis in its alternate position. This places a variable negative bias on the plate of the lower diode section (see D of figure 3).

2. Vary the negative bias-supply potentiometer over its range, and note the changes that occur in the waveform observed at OUTPUT jack, J3.

3. At D in figure 3, record the trace obtained with the potentiometer set for −5 volts.

Effect of Limiting Resistance

1. Set up the limiter chassis to operate as an unbiased negative-lobe limiter. To do this:

a. Connect SS-1 and SS-2 in normal positions.

b. Connect the scope lead to OUTPUT jack, J3, of the limiter.

2. Using a 39,000-ohm resistor at R2, measure the input and output peak voltages obtained.

3. Record these figures in the table, figure 4.

4. Change the limiting resistor (R2) to 100,000 ohms, and repeat the measurements.

5. Change the limiting resistor to 1 megohm, and repeat the measurements.

6. Change the limiting resistor to 2.2 megohms, and repeat the measurements.

Trigger Pulse Limiting

1. Set up equipment that will produce a series of alternate positive and negative trigger pulses. To do this:

a. Connect the Square Wave Generator Chassis, the Differentiator Chassis, and the Series Diode Limiter Chassis as indicated in figure 1B.

b. Adjust the square-wave generator to produce a symmetrical waveform.

c. Measure the frequency of this square wave by comparison with the output of an a-f oscillator.

Frequency _____ cycles

d. From what you have already learned about differentiators, choose a combination of R and C that will produce sharply differentiated pips from the square-wave input. Obtain the instructor's approval of your choice.

Instructor's initials_________

e. Insert these values of R and C in the Differentiator Chassis. Obtain the instructor's approval of the output waveform.

Instructor's initials_______

f. At A in figure 5, record the waveform obtained.

2. Using the results you obtained in this EXPERIMENT, connect the diode limiter (and if necessary, apply bias of the correct polarity at the proper point) to eliminate the negative trigger pulses. At B in figure 5, record the output waveform obtained with this circuit.

3. Connect the diode limiter (biasing it if necessary) to eliminate the positive trigger pulses. At C in figure 5, record the output waveform obtained.

4. Discuss the circuit arrangement, specifying the polarity and amplitude of the bias (if used).

To eliminate the negative trigger pulses, apply positive bias to the cathode of the series diode limiter arranged as a negative-lobe limiter. To eliminate the positive trigger pulses, apply negative bias to the plate of the series diode limiter arranged as a positive-lobe limiter.

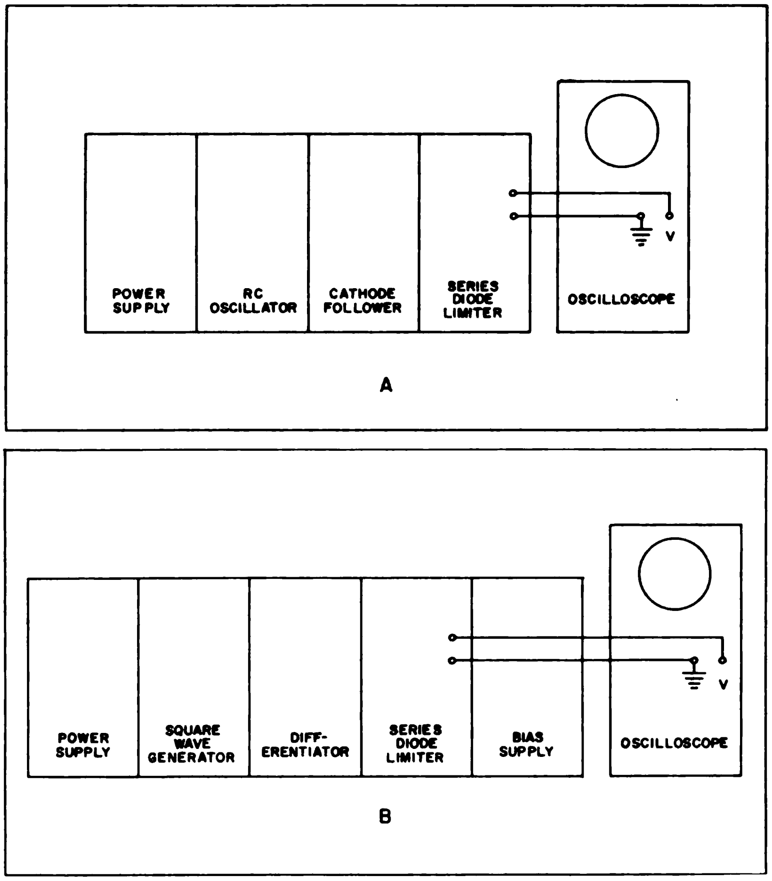


Figure 1. Block Diagrams of Equipment Setup for Series Diode Limiter

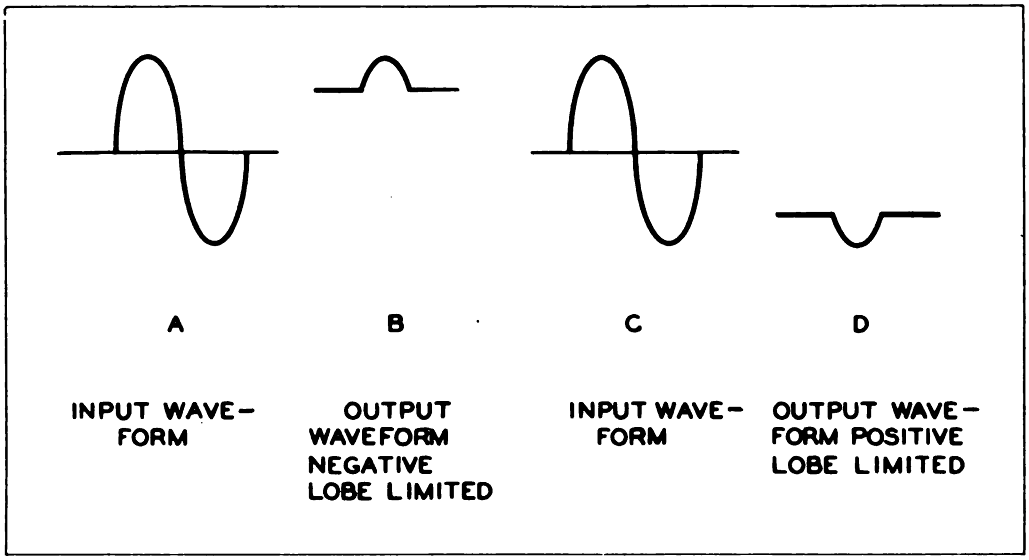

A
B
C
D
INPUT WAVE-FORM
OUTPUT WAVEFORM NEGATIVE LOBE LIMITED
INPUT WAVE-FORM
OUTPUT WAVE-FORM POSITIVE LOBE LIMITED

Figure 2. Effects of Positive- and Negative-Lobe Limiting on Sine Waves

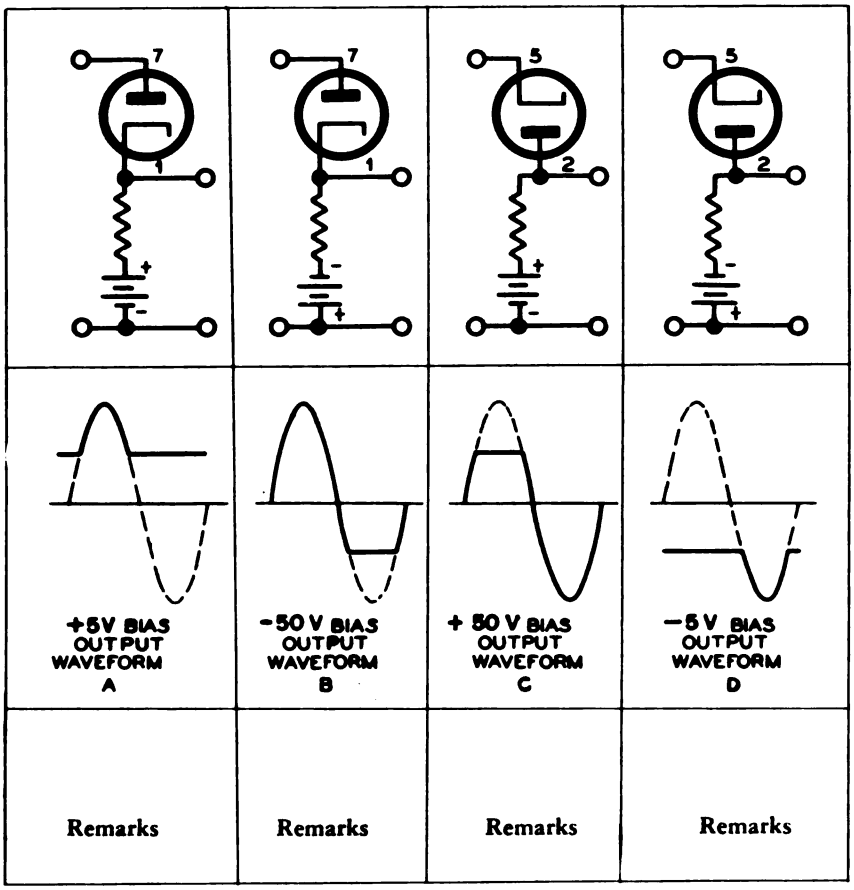

7
1
+
-
+5V BIAS OUTPUT WAVEFORM A
7
1
-
+
-50 V BIAS OUTPUT WAVEFORM B
5
2
+
-
+ 50 V BIAS OUTPUT WAVEFORM C
5
2
-
+
-5 V BIAS OUTPUT WAVEFORM D
Remarks
Remarks
Remarks
Remarks

Figure 3. Series Diode Limiter Circuits, with Waveforms Showing Effects of Limiting Action on Sine Waves

LIMITER RESISTANCE (Ohms)	INPUT PEAK VOLTAGE (Volts)	OUTPUT PEAK VOLTAGE (Volts)
39K		
100K		
1 Meg		
2.2 Meg		

Figure 4. Effect of Limiting Resistance upon Output

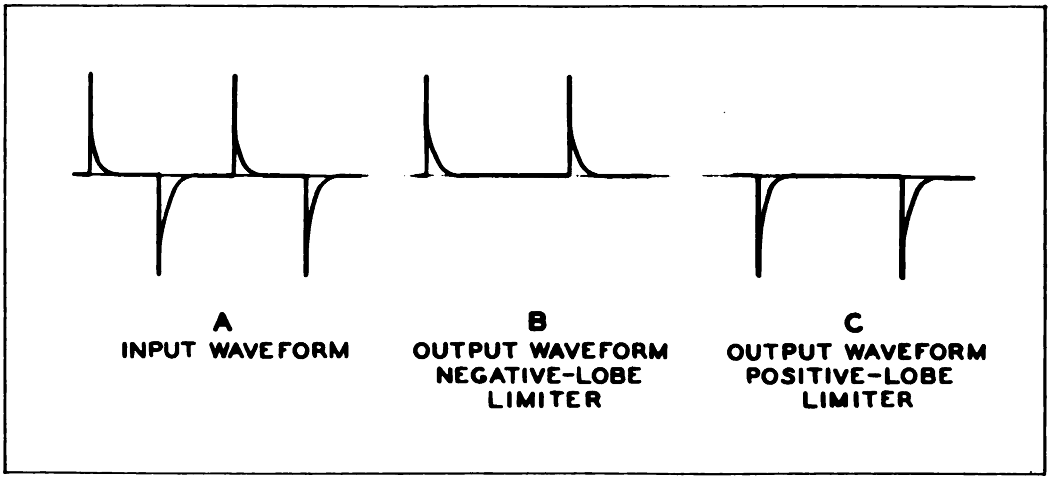


Figure 5. Elimination of Trigger Pulses

CONCLUSIONS

1. Draw a diagram of a series diode circuit used as a negative-lobe limiter, without bias. Draw a similar diagram showing the circuit for a positive-lobe limiter, without bias.

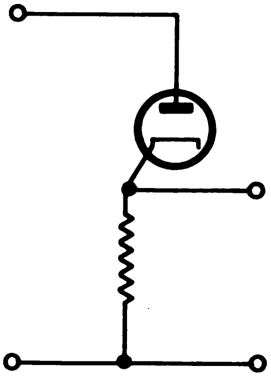
2. Formulate four rules, based on figure 3, that will act as guides in connecting and biasing series diode limiters to obtain any kind of limiting desired.

a. To eliminate all parts of the input waveform except the positive peaks, apply positive bias to the cathode of a negative-lobe limiter.

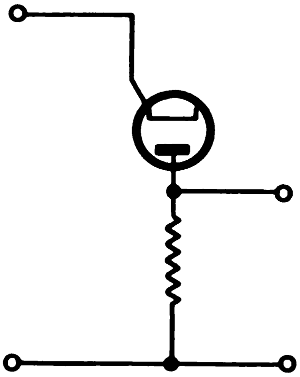
b. To clip off the negative peaks, leaving the rest of the input waveform undistorted, apply negative bias to the cathode of a negative-lobe limiter.

c. To clip off the positive peaks, leaving the rest of the input waveform undistorted, apply positive bias to the plate of a positive-lobe limiter.

d. To eliminate all parts of the input waveform except the negative peaks, apply negative bias to the plate of a positive-lobe limiter.



Negative-Lobe Limiter



Positive-Lobe Limiter

LABORATORY PLAN No. 12

SUBJECT

The parallel diode limiter.

OBJECTIVE

To assist the students in their analysis of the circuit operation of the parallel diode limiter.

MATERIAL REQUIRED

1. Parallel Diode Limiter Chassis.
2. R-C Oscillator Chassis.
3. Cathode Follower Chassis.
4. Bias Supply Chassis.
5. Five-inch oscilloscope, with leads and cross-section screen.
6. Power Supply Chassis.

INTRODUCTION

Limiters find application in circuits in which the input voltage to a stage must be prevented from swinging too far in either the positive or negative direction. They may be used in frequency-modulation circuits, where it is necessary to limit the amplitude of the signal applied to the detection system to a constant value.

SUBJECT MATERIAL

1. Call to the attention of the class any discrepancies observed during the previous laboratory session. Remind the students that, by this time in the course, they are responsible for neat and accurate workmanship.

2. Conduct a brief demonstration, indicating the results expected of the students. Refer to the EXPERIMENT, and follow the steps given there.

3. As the work progresses, move from group to group. By asking pertinent questions, find out if the students understand their results.

CONCLUSIONS

The problems given at the end of the EXPERIMENT, in addition to the other questions, are to be answered and submitted to the instructor before the next laboratory session, for correction and grading.

The parallel diode limiter has a wide and varied usage in limiting signals. It can be connected so as to limit the positive signals at approximately ground potential, in addition to operating in other capacities.

EXPERIMENT No. 12

SUBJECT

The parallel diode limiter.

OBJECTIVE

To familiarize the student with the circuits used in parallel diode limiters; to show how these circuits can suppress either the positive or the negative lobe of an incoming waveform without making any appreciable change in the opposite lobe; to show the effects of bias upon the output waveform; to show the influence of the limiter resistor upon the limiter output; to show how square waves can be produced from sine waves by the use of two biased diodes, connected as parallel diode limiters.

MATERIAL REQUIRED

1. R-C Oscillator Chassis.
2. Cathode Follower Chassis.
3. Five-inch oscilloscope, with leads and cross-section screen.
4. Bias Supply Chassis.
5. Parallel Diode Limiter Chassis.
6. Power Supply Chassis.

INSTRUCTIONS

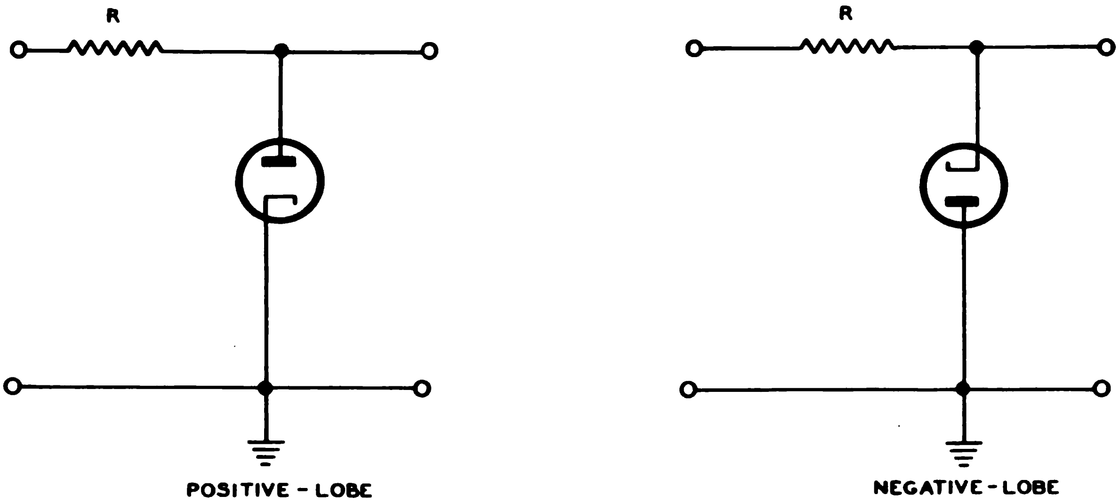
The parallel diode limiter is almost identical with the series diode limiter, except that the output is taken from across the tube, instead of the resistor. A study of the schematic diagrams accompanying this EXPERIMENT, and those in the EXPERIMENT on the series diode limiter, will show the difference. However, because of the different output connection, the behavior of the parallel limiter is, in many respects, the direct opposite of that exhibited by the series limiter. The waveforms taken in this EXPERIMENT will illustrate the point. Both types of limiters are widely used in radar, and must be thoroughly understood.

PROCEDURE

Negative-Lobe Limiting

1. Connect together the R-C oscillator, the cathode follower, the parallel diode limiter, and the scope, as shown in figure 1. The bias supply will not be used at this time.

2. Place a shorting strip in the SS-1 ALT 3 position and remove all other shorting strips.



POSITIVE - LOBE LIMITING

NEGATIVE - LOBE LIMITING

Positive-Lobe and Negative-Lobe Parallel Diode Limiters

3. At A in figure 2, record the waveform observed at the input of the limiter. (Reduce the output of the oscillator for undistorted output.)

4. At B in figure 2, record the waveform observed at the output of the limiter.

Positive-Load Limiting

1. Place SS-1 in ALT. 2 position. This disables the right-hand diode section (pins 1 and 7) and places the left-hand diode section (pins 2 and 5) in the circuit.

2. Note and record the difference between the connections of these two sections.

3. At C in figure 2, record the waveform observed at the input of the limiter.

4. At D in figure 2, record the waveform observed at the output of the limiter.

Effect of Bias

Positive Bias on Cathode of Left-Hand Diode Section (pins 2 and 5)

1. Place SS-1 in ALT. 1 position and connect SS-1 of the Bias Supply Chassis in its normal position. This places the variable positive bias between the cathode of the left-hand diode section (pin 5) and ground.

2. Vary the bias-supply potentiometer over its entire range, and note the effect on the output waveform.

3. At A in figure 3, record the output trace obtained with the bias potentiometer set at +4v.

4. In the space provided for remarks, at A in figure 3, record your observations of the effect of varying the bias from zero to approximately 50 volts.

Negative Bias on Cathode of Left-Hand Diode Section pins (2 and 5)

1. Place SS-1 of the Bias Supply Chassis in its alternate position. This places a negative bias on the cathode of the left-hand diode section (pin 5).

2. Vary the bias-supply potentiometer which controls the negative bias, and note the effect on the output waveform.

3. At B in figure 3, record the output trace obtained with the potentiometer set at − 10 v.

4. In the space provided for remarks at B in figure 3, record your observations of the effect of varying the bias from zero to approximately − 50 volts.

Positive Bias on Plate of Right Hand Diode Section (pin 7)

1. Place SS-1 in Alt. 4 position.

2. Place SS-1 of the Bias Supply in its normal position, placing positive bias on the plate.

3. Vary the positive bias potentiometer over its range, and note the change in output waveform that occurs.

4. At C in figure 3, record the output trace obtained with the potentiometer at +40 v.

5. In the space for remarks, at C in figure 3, record your observations of the effect of varying the bias from zero to approximately 50 volts.

Negative Bias on Plate of Right-Hand Diode Section (pins 1 and 7)

1. Place SS-1 of the Bias Supply Chassis in its alternate position. This places a negative bias on the plate of the right-hand diode section (pin 7).

2. Vary the bias-supply potentiometer which controls the negative bias, and note the changes that occur in the output waveform.

3. At D in figure 3, record the output trace obtained with the potentiometer at − 3 v.

4. In the space provided for remarks, at D in figure 3, record your observations of the effect of varying the bias from zero to approximately − 50 colts.

Effect of Limiter Resistor

1. Place SS-1 in ALT. 2 position. This places the left-hand diode section (pins 2 and 5) in the circuit. Insert a 47,000-ohm resistor for R2.

2. Measure the peak input voltage and the peak voltage appearing at the output jack J3.

3. Record these readings, and sketch the output waveform at the appropriate places in figure 4.

4. Repeat these measurements, using a 100,000-ohm, and a 1-megohm resistor, successively, at R2. Record your results in figure 4.

Production of Square Waves

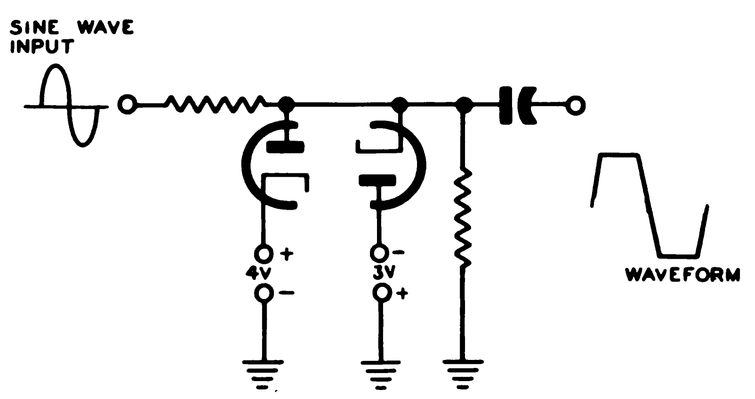
1. Set up the circuit in such a way that it will clip off both the positive and the negative peaks of the input sine wave. Use the information you have already gained in this EXPERIMENT in deciding upon a suitable circuit. Have the instructor check your connections before proceeding.

Instructor's initials______

2. Adjust the equipment so as to produce a square wave having a peak-to-peak amplitude of 5 volts. Secure the instructor's initials when this step has been completed satisfactorily.

Instructor's initials______

3. In the space provided below, describe the circuit used to produce this square wave. Include a circuit diagram, and specify the bias voltage(s) used, as well as the peak input voltage required.



Production of Square Waves with a Parallel Diode Limiter

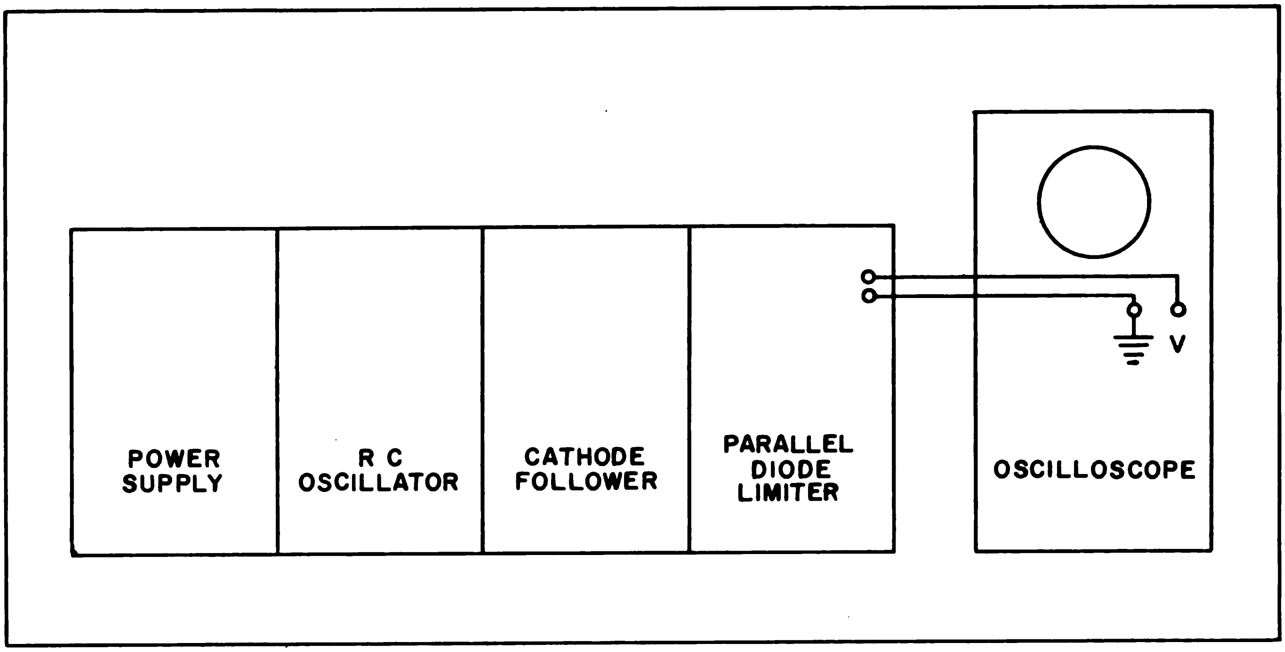
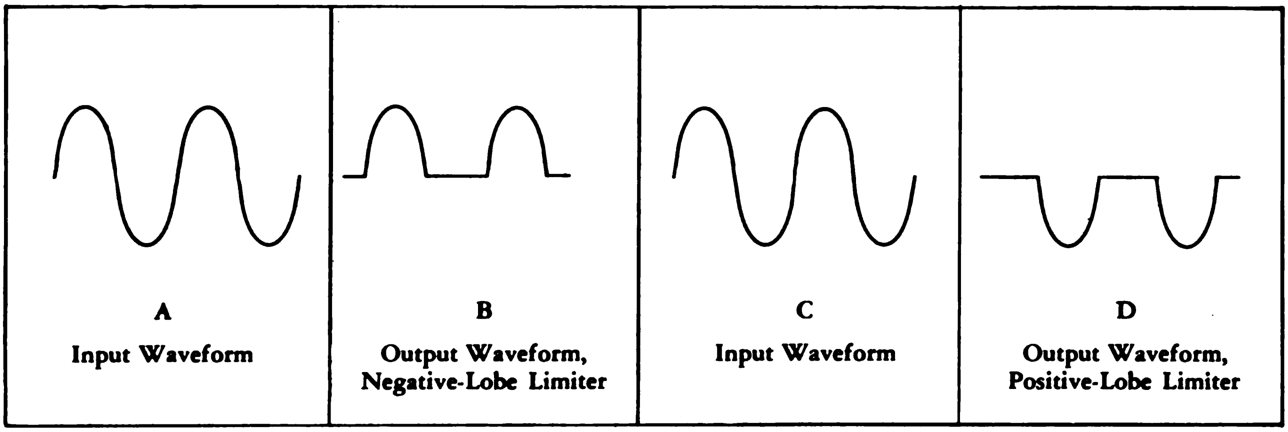


Figure 1. Block Diagram of Equipment Setup for Parallel Diode Limiter



A
Input Waveform

B
Output Waveform, Negative-Lobe Limiter

C
Input Waveform

D
Output Waveform, Positive-Lobe Limiter

Figure 2. Effects of Negative-Lobe and Positive-Lobe Limiting

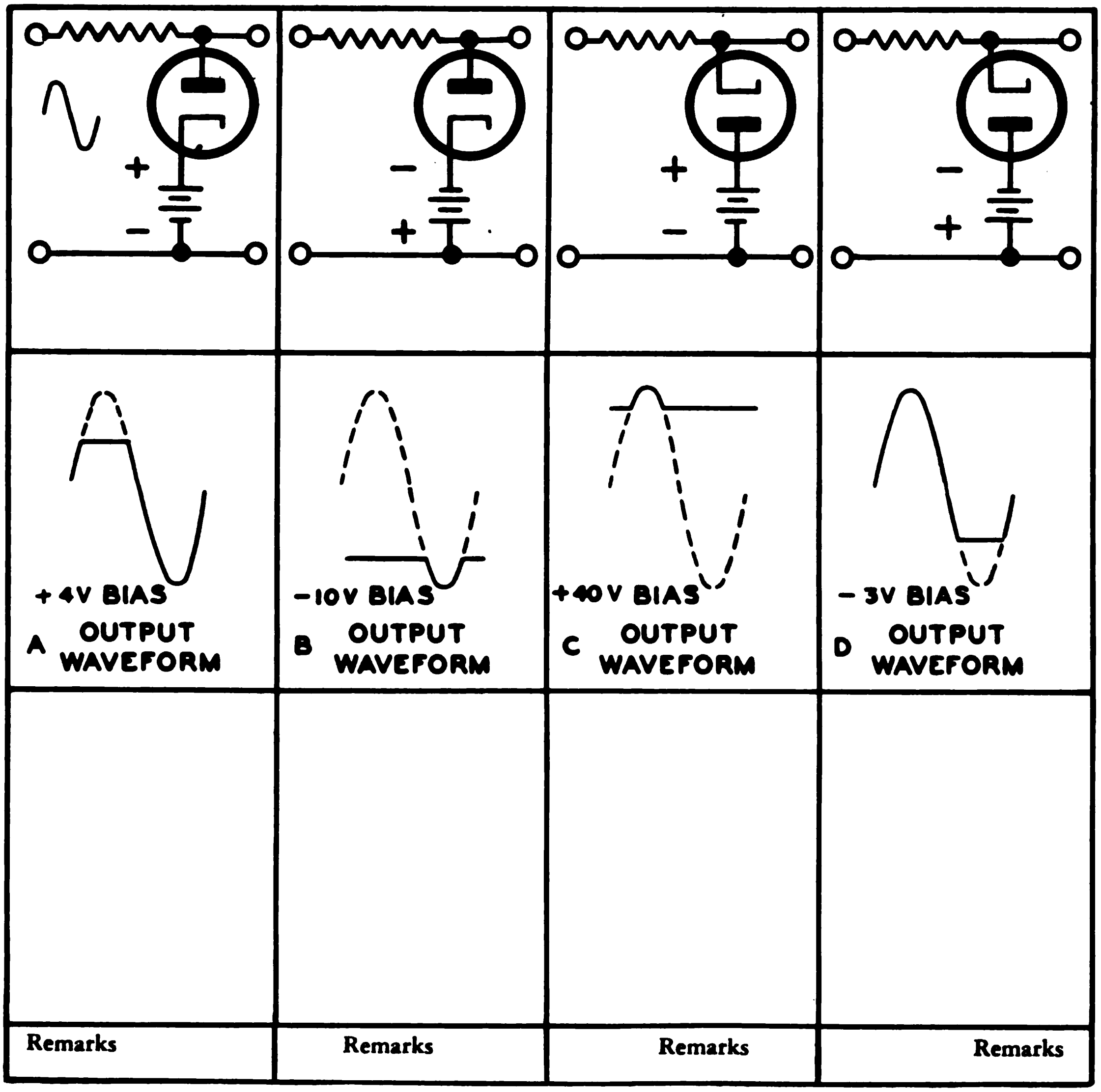


Figure 3. Effects of a Biased Parallel Diode Limiter upon a Sine Wave

LIMITER RESISTOR	PEAK INPUT VOLTAGE	PEAK OUTPUT VOLTAGE	OUTPUT WAVEFORM
47,000 ohms			
100,000 ohms			
1 megohm			

Figure 4. Effect of Limiting Resistor upon Peak Output Voltage

CONCLUSIONS

1. Formulate four rules describing how positive and negative biases affect the output of a parallel diode limiter circuit

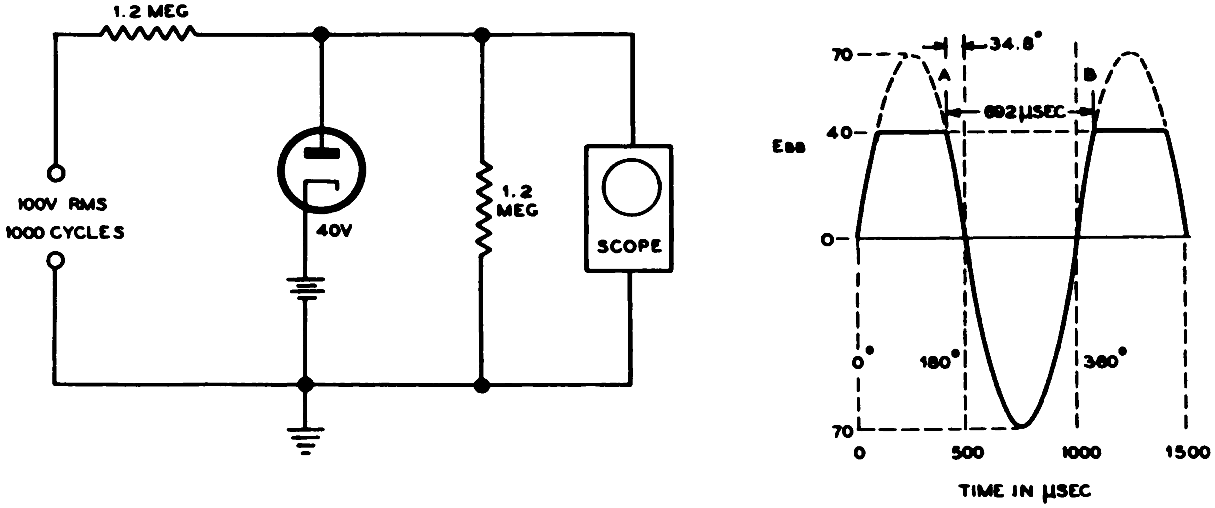
a. To remove all the wave above a certain positive (+) value, apply positive bias to the cathode of a positive limiter.

b. To remove all the wave above a certain negative (−) value, apply negative bias to the cathode of a positive limiter.

c. To remove all the wave below a certain positive (+) value, apply positive bias to the plate of a negative limiter.

d. To remove all the wave below a certain negative (−) value, apply negative bias to the plate of a negative limiter.

2. In the diagram shown below, how many microseconds elapse between points A and B? Show all your work.

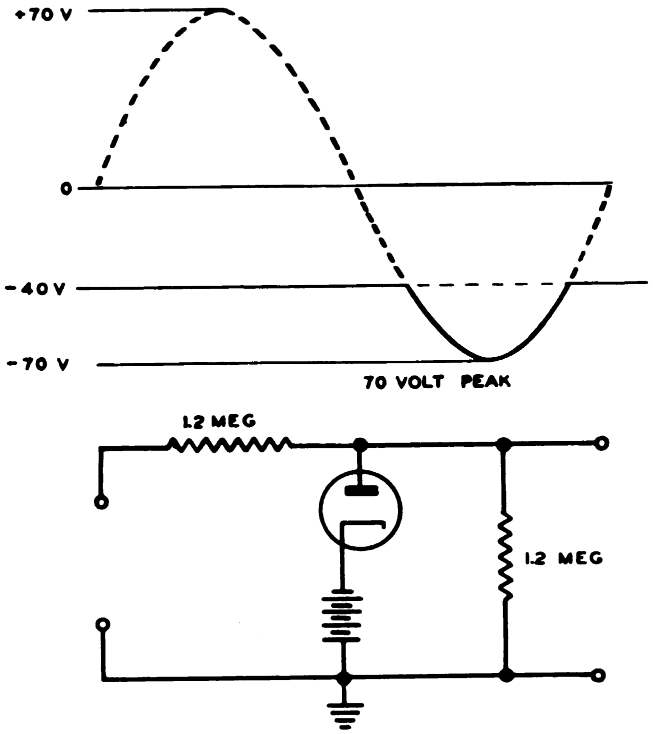


Parallel Diode Limiter and Ouptut Waveform

3. What will be the peak-to-peak amplitude of the waveform appearing on the scope?

E (Peak-to-peak) = Positive peak + Negative peak = 40+70 = 110 volts.

4. Draw the waveform that would be observed on the scope if the bias battery were reversed. Indicate the peak voltages; indicate whether these voltages are positive or negative.



Output Waveform with Bias Polarity Reversed

LABORATORY PLAN No. 13

SUBJECT

The triode limiter.

OBJECTIVE

To assist the student in the testing and operational checking of the triode limiter circuit.

MATERIAL REQUIRED

1. Triode Limiter Chassis.
2. Vacuum-tube voltmeter with leads.
3. Five-inch oscilloscope with leads.
4. Laboratory Chassis Mounting Rack.
5. A-F oscillator with leads.
6. Power Supply Chassis.
7. Lead, 12" long, with pin jack on one end and solder lug on the other.

INTRODUCTION

The triode limiter is essentially a Class A resistance-coupled amplifier, which, under certain conditions, may be used to produce several types of limiting.

SUBJECT MATERIAL

1. Familiarize the students with the Triode Limiter Chassis and the individual parts, as was done with other chassis in previous EXPERIMENTS.

2. Check the resistance and voltage measurement tables compiled by the students.

3. Conduct a brief demonstration, pointing out the results to be expected in the EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there.

4. Insist that the schematic diagrams, drawn to show how the circuit may be rearranged for different types of limiting, be accurate, uniform, and neat.

CONCLUSIONS

In radar it is often desirable to distort waves, in order to use them as triggers or drivers for subsequent circuits. The last few EXPERIMENTS have illustrated typical radar wave-distorting circuits. Limiter circuits of the type studied in this EXPERIMENT are particularly useful in removing undesired positive or negative pulses from a waveform. They are also used in the process of converting sine waves into square waves.

EXPERIMENT No. 13

SUBJECT

The triode limiter.

OBJECTIVE

To show that a resistance-coupled amplifier can, under suitable conditions, produce the following types of limiting:

1. Grid limiting.
2. Saturation limiting.
3. Cutoff limiting.
4. Overdriven-amplifier limiting.

MATERIAL REQUIRED

1. Triode Limiter Chassis.
2. Vacuum-tube voltmeter with leads.
3. Five-inch oscilloscope with leads.
4. Laboratory Chassis Mounting Rack.
5. A-F oscillator with leads.
6. Power Supply Chassis.
7. Lead, 12" long, with pin jack on one end and solder lug on the other.

INSTRUCTIONS

The last of three types of limiters to be studied will be tested during this EXPERIMENT. This device will be used later in the course, both as a limiter and as an ordinary Class A resistance-coupled amplifier.

PROCEDURE

Testing

1. Study the schematic diagram included in this EXPERIMENT.
2. Obtain the materials listed in 1 through 7 of MATERIAL REQUIRED.
3. Perform resistance and voltage measurements similar to those performed in previous EXPERIMENTS. Arrange the results in the form of a table, showing anticipated and measured resistances and voltages, and submit for the approval of the instructor. *Do not insert the tube* until these tests have been completed.

Instructor's initials_______

Operation as a Class A Amplifier

1. Remove the grid-limiting resistor, R2, and replace it with a shorting strip.
2. Connect the a-f oscillator to the INPUT jack.
3. Set the Triode Limiter Chassis potentiometer for zero bias on the cathode.
4. Connect the scope lead to the INPUT jack. In this position, the scope will indicate the waveform of the signal being applied to the grid of the tube.
5. At A in figure 1, record the waveform observed.
6. Transfer the scope lead to the OUTPUT jack; at B in figure 1, record the plate-voltage waveform observed. Note that the amplitude of this waveform greatly exceeds the amplitude of the grid-input signal, indicating that the tube is amplifying.
7. Adjust the output voltage of the a-f oscillator and the setting of the bias potentiometer on the triode limiter until a pure sine wave of the *greatest possible amplitude* is obtained at the OUTPUT jack. Continue the adjustments until there is no flattening of either positive or negative peaks.
8. Measure the a.c. voltage between grid and ground and the ac. voltage between plate and ground.
9. Compute the maximum gain of the triode limiter when acting as a Class A amplifier. Record this gain in the table provided below, for future reference.

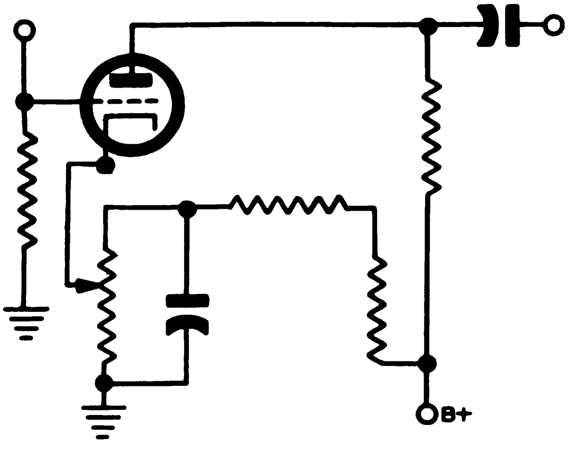
Grid-to-ground volts, a.c.	2.25
Plate-to-ground volts, a.c.	72
Gain	32

Typical Voltages, Class A Amplifier

10. In the space provided, make a neat drawing of the circuit used in the chassis when it is connected for use as a Class A amplifier. Draw the same circuit in the space provided in figure 1.

Operation as a Cutoff Limiter

1. Remove the shorting strip, and replace the grid-limiting resistor, R2. The chassis is now connected as a grid limiter.
2. In the space provided, draw a neat diagram of the circuit used in the chassis when it is connected for grid limiting. Draw the same circuit in the space provided in figure 1.
3. Turn the triode-limiter potentiometer to reduce the bias to zero.
4. Apply the output voltage of the a-f oscillator to the INPUT jack of the limiter.



Schematic, Class A Amplifier

5. Connect the scope lead to the grid end of R2 and observe the waveform appearing at the limiter grid. Record this waveform at C in figure 1.

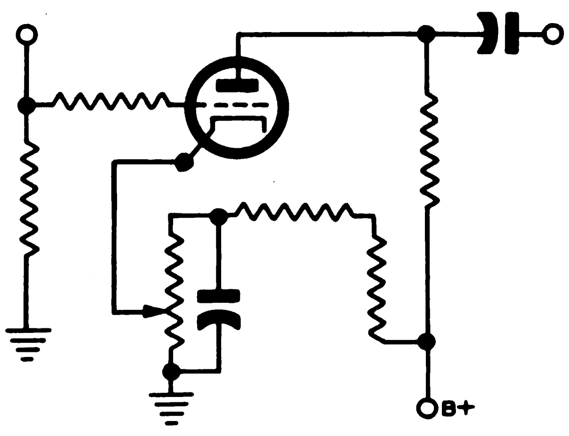
6. Transfer the scope lead to the OUTPUT jack, and observe the waveform appearing at the plate of the limiter tube. Record this waveform at D in figure 1.

7. Rotate the bias potentiometer over its entire range, and note the change in the waveforms observed at the grid and at the plate of the limiter tube. Describe and explain these changes.

Increasing the bias decreases the clipping of the grid positive lobes. This occurs because grid current is decreased. Too much bias drives the tube to or toward cutoff, and clips positive plate-voltage lobes, due to cutoff limiting action (see next operation, below).

What is the best value of bias voltage for a grid-limiting circuit? Why? Record this bias on the grid limiter schematic drawn in step 2, above.

Zero bias is best, because the limiting is dependent upon grid current. The use of a negative grid bias discourages the flow of grid current, and hampers grid-limiting action.



Schematic Diagram of Grid Limiter

Operation as a Cutoff Limiter

1. Remove the limiter resistor, R2, and replace it with a shorting strip. With sufficient signal drive, the chassis will now function as a cutoff limiter.

2. In the space provided, draw a neat diagram of the circuit used in the chassis for cutoff limiting. Draw the same circuit in the space provided in figure 1.

3. Set the bias potentiometer to apply maximum negative bias to the grid.

4. Apply the output of the a-f oscillator to the INPUT jack, and adjust the a-f oscillator to deliver all the voltage of which it is capable. If the output of the oscillator is insufficient, add the audio voltage amplifier ahead of the limiter.

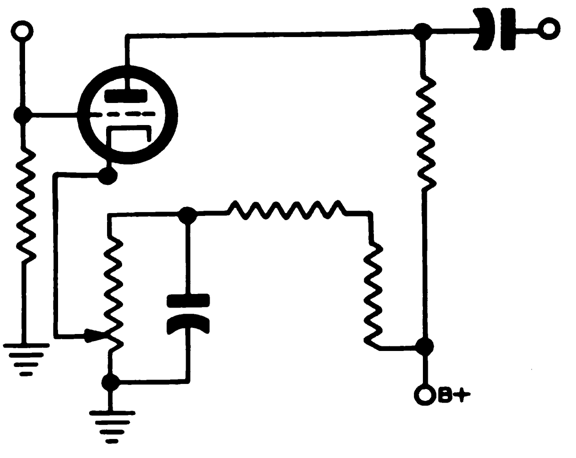
5. Connect the scope to the INPUT and observe the waveform being impressed upon the grid. Record this waveform at E in figure 1.

6. Transfer the scope lead to the OUTPUT jack, and observe the waveform appearing at the plate. Record this waveform at F in figure 1.

7. While observing the plate waveform, vary the bias potentiometer over its entire range. Describe and explain the change in waveform that occurs. Sketch the waveform at various settings of the bias potentiometer. Determine and record, on the cutoff limiter schematic diagram, the bias at which plate-current cutoff occurs.

Operation as a Saturation Limiter

1. Connect the a-f oscillator to the INPUT



Schematic Diagram of Cutoff Limiter

jack of the Triode Limiter Chassis. Remove resistor R3 and replace it with a 2.2 megohm resistor. The chassis is now connected as a saturation limiter.

2. In the space provided, draw a neat diagram of the circuit used in the chassis when it is connected for saturation limiting. Draw the same circuit in the space provided in figure 1.

3. Adjust the bias potentiometer of the Triode Limiter Chassis for zero bias.

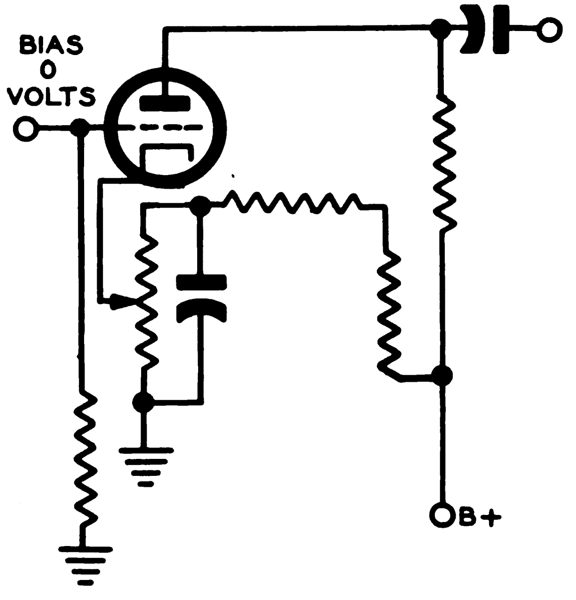
4. Set the control knob on the a-f oscillator for zero a-c voltage at the tube grid.

5. Connect the scope lead to the OUTPUT jack.

6. Turn the a-f oscillator control knob slowly. Note that a sine wave appears on the scope. Turn the control knob to apply an increasing a-c voltage to the tube grid. Observe that the negative peaks of the sine wave begin to flatten. Turn the control knob still further, and note the setting at which the positive peaks also begin to flatten.

CAUTION:

DO NOT EXPECT THE NEGATIVE PEAKS TO BECOME PERFECTLY FLAT. THEY WILL BECOME ROUNDED, THEN PEAKED, BUT NEVER FLAT, UNLESS THE INPUT VOLTAGE IS RAISED TO A VALUE CAPABLE OF DAMAGING THE TUBE. DO NOT IMPRESS MORE THAN 40 VOLTS BETWEEN GRID AND CATHODE OF A 6AB4 OR DAMAGE WILL RESULT. TURN THE CONTROL KNOB BACK TO A POINT WHERE THE NEGATIVE PEAKS ARE FLATTENED, BUT THE POSITIVE PEAKS HAVE NOT QUITE STARTED TO FLATTEN. MEASURE THE BIAS AT THIS POINT, AND RECORD IT ON THE SATURATION-LIMITER SCHEMATIC. (USE THE AF VOLTAGE AMPLIFIER, IF NECESSARY, WITH THE SIGNAL GENERATOR.



Schematic Diagram of Saturation Limiter

7. At H in figure 1, record the waveform observed at the limiter plate (OUTPUT jack).

8. Transfer the scope lead to the INPUT jack; at G in figure 1, record the waveform observed. This waveform should be sinusoidal, indicating that all the limiting action is taking place in the plate circuit of the tube.

9. Rotate the a-f oscillator control knob over its entire range (subject to the CAUTION given above), noting the waveforms obtained at both the grid and plate of the limiter tube. Sketch these waveforms for several settings of the potentiometer, and discuss the reasons for the changing appearance of these waveforms.

Operation as an Overdriven Amplifier

1. The overdriven amplifier employs a combination of cutoff limiting and saturation limiting. The input a-c voltage to the limiter grid is increased to a point where the tube is driven to plate-current saturation during positive grid peaks, and is cut off entirely for a considerable period during negative grid peaks. Its action has already been observed (but not studied) during the preceding observations on the saturation limiter.

2. In the space provided below, draw a neat diagram of the circuit used in the chassis when it is connected for use as an overdriven amplifier. Draw the same circuit in the space provided in figure 1.

3. Turn the a-f oscillator output control to produce the maximum a-c voltage on the limiter grid (subject to the CAUTION given above).

4. Connect the scope lead to the OUTPUT jack; at J in figure 1, record the plate waveform obtained with the Triode Limiter Chassis potentiometer set for zero cathode bias on the tube.

5. Transfer the scope lead to the INPUT jack; at I in figure 1, record the grid waveform observed.

6. Replace the scope lead in the OUTPUT jack. Vary the triode-limiter potentiometer over its entire range, to change the bias of the limiter tube from zero to a high negative value.

7. Note that the plate waveform can be made symmetrical or asymmetrical, at will. Sketch the waveforms obtained at several settings of the

limiter potentiometer. Explain *fully* the changes in waveform obtained.

CONCLUSIONS

Discuss in approximately 300 words, what you have learned about limiters from this EXPERIMENT.

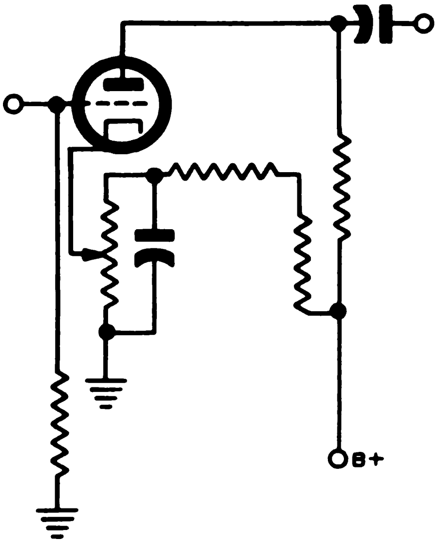
Four types of triode limiters were studied in this EXPERIMENT.

1. The grid limiter is a resistance-capacitance coupled amplifier with a large resistance inserted between the input and the grid. The circuit ordinarily operates at zero bias. Any portion of the incoming signal that is negative is amplified essentially without distortion. Any positive-going signal causes grid current to flow, dropping the signal voltage across the resistor inserted between input and grid. Thus the grid is held approximately at zero, and the positive portion of the incoming wave is limited. The output at the plate is in the form of positive-going half cycles on a reference voltage level.

2. The cutoff limiter is connected in the same manner as an ordinary resistance-capacitance coupled amplifier. It is so biased that, during a part of the cycle, the tube goes into cutoff. The customary bias point for this type of limiter is the cutoff point. The output at the plate with cutoff bias consists of half cycles going negative from B+.

3. The saturation limiter is connected as a resistance-capacitance coupled amplifier. It is normally biased at zero. When the signal goes negative, it is amplified essentially without distortion. When it goes positive, tube current reaches a high value, and a large signal voltage appears across the plate resistance. When this voltage approaches the B+ value, the tube will not draw a higher current. Hence the waveform on the plate is in the form of positive-going half cycles on a low reference-voltage level.

4. The overdriven amplifier is, in its circuit components, identical with the saturation limiter. It is biased between zero and cutoff. The signal must be large enough to drive the tube into cutoff on the negative swings, and into saturation on the positive swings. The waveform on the plate will have both peaks limited. This gives approximately a square wave.



Schematic Diagram of Overdriven Amplifier

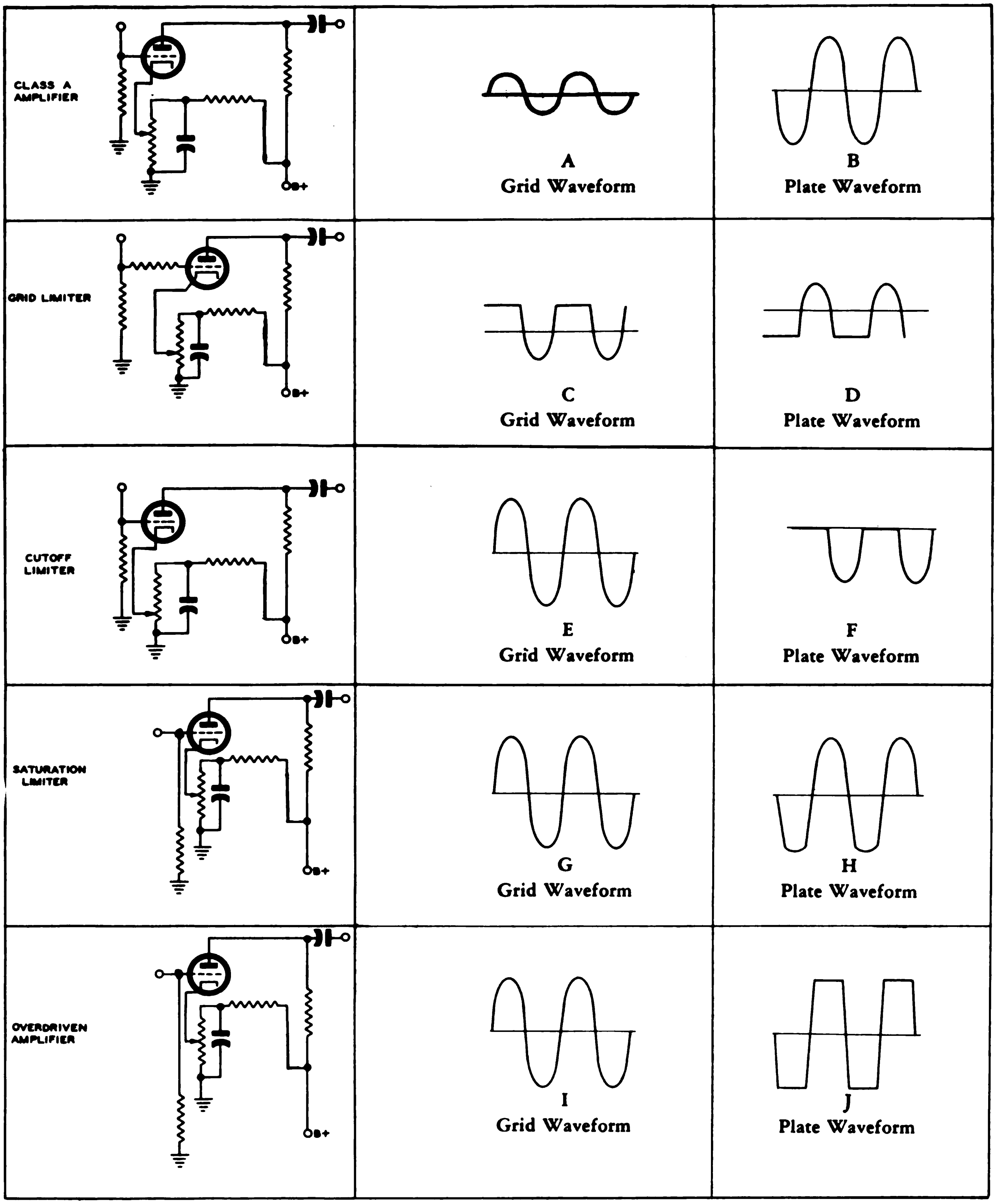
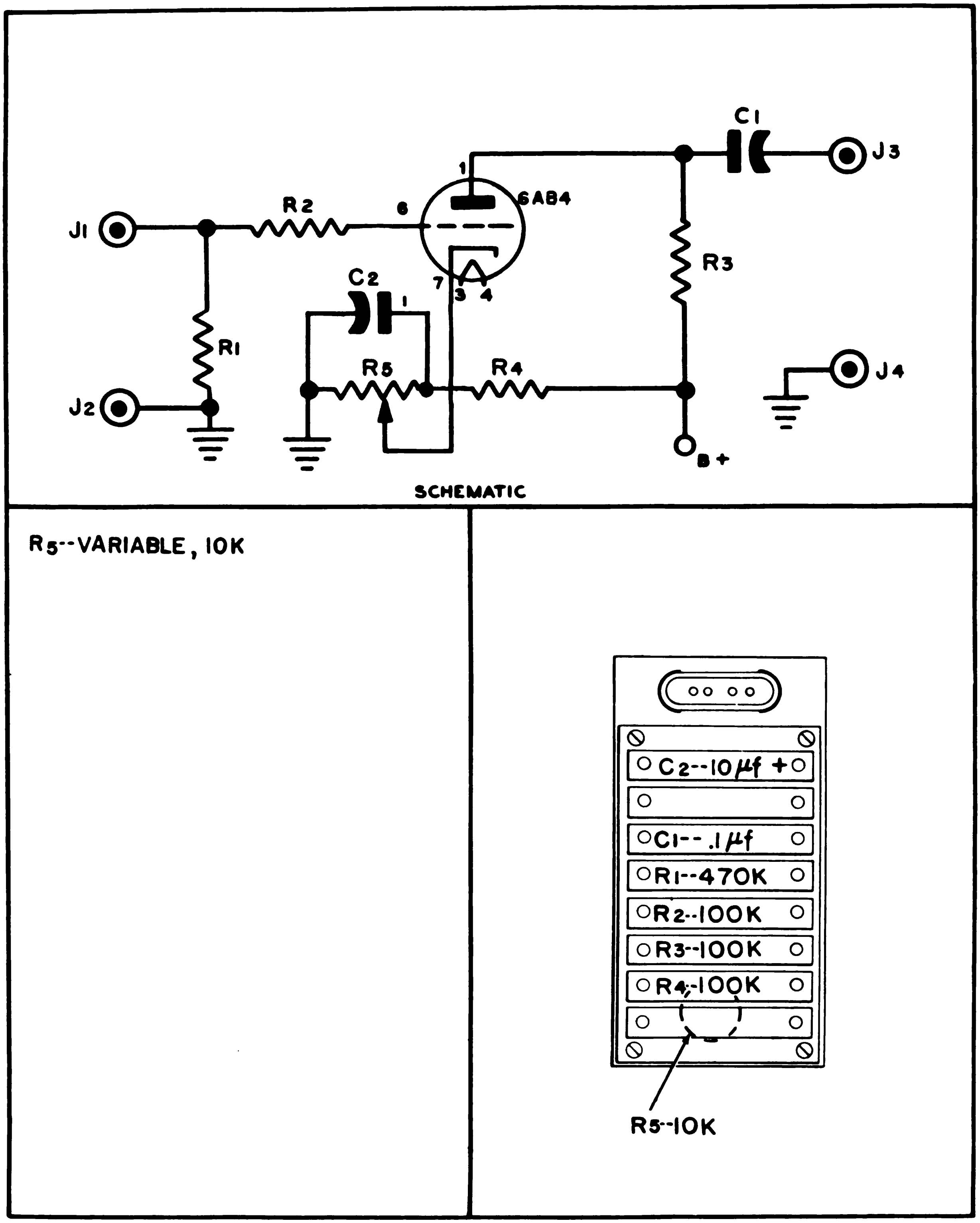


Figure 1. Waveforms Obtainable from the Triode Limiter Chassis



Schematic Diagram of Triode Limiter Chassis

INFORMATION SHEET

TIME MEASUREMENTS BY MEANS OF A LINEAR SWEEP

In studying the waveforms developed in radar equipment, it is sometimes desirable to be able to measure the time that elapses between pulses; to measure the width (in microseconds) of a given pulse; or to determine how many microseconds are required for a "square" wave to rise from zero to its maximum value.

Very accurate measurements can be made by means of a synchroscope equipped to supply marker pulses, but this type of instrument is not always available. However, measurements of reasonable accuracy can easily be made by means of an ordinary oscilloscope with a cross-section screen and an audio-frequency oscillator. (If a cross-section screen is not available, a small flexible ruler or similar measuring device can be substituted.)

A worked-out example of the procedure is shown at A, B, and C of figure 2.

Method 1

Suppose that it is required to find the width, in microseconds, of the rectangular pulses shown at A in figure 2:

1. Set up the equipment as indicated in figure 1.

2. Display on the oscilloscope the pulsed waveform to be measured. To do this, proceed as follows:

a. Connect the source of pulses to the vertical-deflection plates of the scope.

b. Adjust the frequency controls of the scope until three cycles of the pulsed wave appear on the screen.

> NOTE: *Do not change the horizontal-amplification control of the scope after making this adjustment.* To do so would change the calibration of the scope, and would destroy the accuracy of the readings.

c. Note and record the number of horizontal screen divisions covered by the pulse to be measured.

3. Calibrate the oscilloscope as follows:

a. Disconnect the pulse-generator lead from the vertical-deflection plates of the scope, and replace it with the output lead of an audio-frequency sine-wave generator (a-f oscillator).

b. Adjust the frequency dial of the a-f oscillator to produce three cycles on the scope. The a-f oscillator is now operating at the same frequency as the pulse generator.

Remember, do not touch the horizontal-amplification knob of the scope.

c. Determine the number of microseconds represented by each screen division. For example, if the frequency dial of the a-f oscillator reads 1000 cycles, it is known that each cycle represents 1/1000 of a second, or 1000 microseconds. Suppose that the distance between two adjacent sine-wave peaks is found to be 10 divisions. This indicates that 10 divisions are equal to 1000 microseconds, and that one division represents 100 microseconds.

4. Measure the width of the pulses as follows:

a. Refer to your notes, and determine the width (in divisions) of the observed pulses, as measured in step 2.

b. Multiply this number of divisions by the number of microseconds represented by one division. For example, suppose that the pulse was found to be two divisions wide. Knowing that each division represents 100 microseconds, it is clear that the pulse has a width of 200 microseconds (2 divisions × 100 microseconds).

In a similar manner, the time elapsing between any two points on a pulse can be determined. It is first necessary to note how many horizontal divisions separate the two points whose time difference is to be measured. Then multiply this number of divisions by the number of microseconds represented by each division.

Obviously, the frequency calibration of the oscillator dial must be accurate. It can be checked easily by the method described in the INFORMATION SHEET on frequency measurements by means of an oscilloscope. The data in the table in C of figure 2 will be helpful in determining the number of microseconds represented by one division of the oscilloscope screen, for a given setting of the sweep-frequency and horizontal-amplification controls.

Method 2

Another method of time measurement that can be used on low-frequency pulses is shown in figure 3. The procedure is as follows:

1. Connect the equipment as shown in figure 1.

2. Display one or more pulses on the scope screen, and spread them to any convenient width. Note and record the number of horizontal divisions covered by the pulse whose width is to be measured. *Do not change the setting of the horizontal-amplification knob thereafter.*

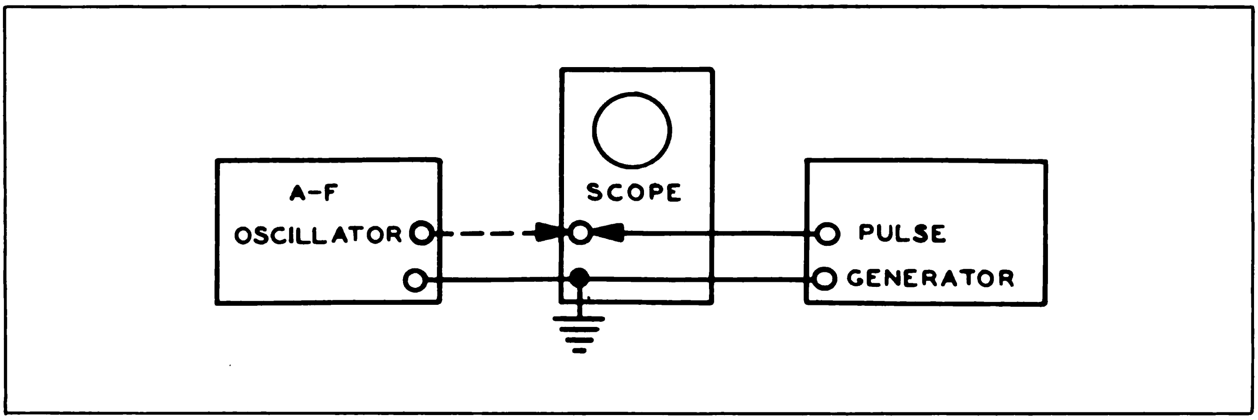
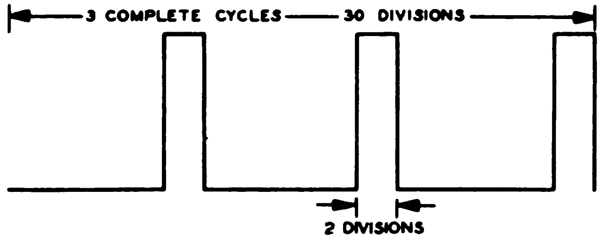
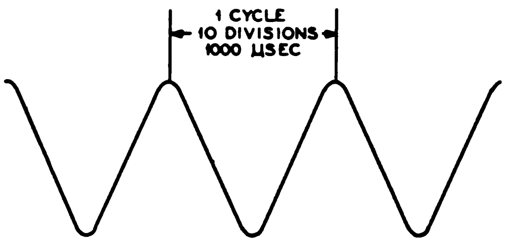


Figure 1. Block Diagram of Equipment Used in Measuring Pulse Width



A. Three Complete Cycles on the Scope Screen

Adjust scope to present three complete cycles of waveform to be observed. Spread trace horizontally to cover 30 divisions on scope screen. Note width (in divisions) of pulse nearest center of trace.



B. Three Complete Cycles (Peak to Peak) on the Scope Screen

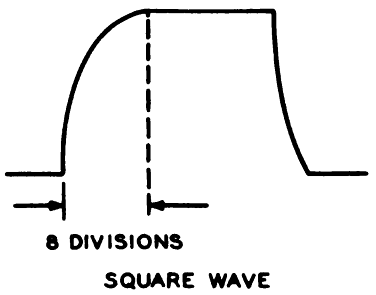
Disconnect pulse generator and substitute a sine-wave generator. Tune oscillator until three complete cycles (peak to peak) appear. *Do not change horizontal-amplification knob of scope.* Note number of horizontal divisions separating adjacent peaks nearest center of trace. Calculate number of microseconds elapsing between peaks (microseconds = 1,000,000/ frequency in cycles).

A-F Osc. Freq. (cycles)	Period (μsec.)	μsec. per Division (peaks 10 div. apart)
60	16,667	1667
100	10,000	1000
300	5000	500
500	2000	200
1000	1000	100
3000	333	33
5000	200	20
10,000	100	10
20,000	50	5
30,000	33	3.3

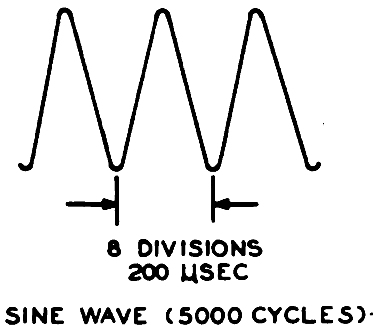
As noted in A, above, the pulse used in this example occupies a width of two screen divisions. Since each cycle (1000 μsec.) occupies 10 divisions, one division must represent 100 μsec. Therefore, this pulse (two divisions wide) must last for 200 μsec.

C. Table Showing How Scope Screen Can Be Calibrated

Figure 2. Time Measurement by Means of a Linear Sweep—Method 1



Spread the square wave so that it occupies most of the scope screen. Note the number of horizontal divisions lying between base line and flat-top portion of wave (eight divisions in this case).



Substitute a-f oscillator for pulse generator. ***Without changing horizontal amplification,*** tune a-f oscillator until two successive peaks are eight divisions apart. Read frequency of a-f oscillator from oscillator frequency dial. Determine number of microseconds elapsing between peaks by the formula:

$$\text{Microseconds} = \frac{1{,}000{,}000}{\text{frequency in cycles}}$$

In the case of a 5000-cycle wave, the elapsed time between peaks is 1,000,000/5000 = 200 microseconds. (Refer also to table in C of figure 2.)

Required: To find the number of microseconds that elapse between the instant when the square-wave voltage starts to rise and the instant when it reaches its maximum amplitude.
Answer: 200 microseconds.

Figure 3. Time Measurements by Means of a Linear Sweep—Method 2

3. Disconnect the pulse generator from the scope, and connect an a-f oscillator to the vertical input of the scope.

4. Vary the frequency dial of the oscillator until adjacent sine-wave peaks are separated by exactly the same number of divisions measured in step 2.

5. Determine how many microseconds elapse between adjacent peaks, by using the formula:

$$\text{Microseconds} = \frac{1{,}000{,}000}{\text{frequency in cycles}}$$

LABORATORY PLAN No. 14

SUBJECT

Analysis of a wave-shaping chain.

OBJECTIVE

To help the students analyze the process of converting a sine wave to one used for triggering or marking pulses. Also, to familiarize the students with the problems arising when several wave-shaping circuits are connected in cascade.

MATERIAL REQUIRED

1. Triode Limiter Chassis.
2. Differentiator-Integrator Chassis.
3. Parallel Diode Limiter Chassis.
4. Bias Supply Chassis.
5. Five-inch oscilloscope with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.

INTRODUCTION

It is frequently necessary in radar equipment to convert a sine wave into a series of narrow, accurately timed pulses. These pulses may be used to start a sequence of operations (in which case they are called "timing pulses"), to furnish adjustable calibration marks ("marker pulses") for display upon the scope screen, and for many other functions that will be studied later in the course.

This EXPERIMENT will show the student one method of producing pulses that are spaced with considerable accuracy. It will also acquaint the student with some of the routine difficulties encountered when several units are connected together to form a chain.

SUBJECT MATERIAL

1. Have the student set up an overdriven amplifier to produce a square-wave output. Approve the waveform before the student continues.

2. The student is to calculate a set of values for R and C in the differentiator circuit, observing the following considerations:

a. The RC time constant must be very short, as compared with the period of the waveform to be differentiated.

b. R must be large as compared with the plate load resistance of the preceding stage, in order to avoid loading the circuit.

3. Give the student your approval when his calculations are satisfactory.

4. Insist that the waveform observed at the output of the differentiator circuit be recorded neatly and accurately.

5. Have the student set up the Parallel Diode Limiter Chassis to produce positive pulses only at the output. Repeat step 4, above.

6. Next, have the students rearrange the parallel diode limiter circuit to produce only negative pulses at the output. Repeat step 4.

The student should measure the time in microseconds that elapses between two successive negative pulses at the output. The width of the pulse should be measured at the base of the waveform, when the amplitude of the pulses are adjusted to 10 volts, peak.

CONCLUSIONS

The narrow pulses produced by this wave-shaping chain can be used to trigger oscillators into action, to force a tube grid above cutoff, so that the tube will conduct for a short period, or to modulate radio frequencies into brief pulses. All of these functions are essential in radar circuits.

EXPERIMENT No. 14

SUBJECT

Analysis of a wave-shaping chain.

OBJECTIVE

To show how a sine wave can be converted into a series of narrow pulses of either positive or negative polarity; to accustom the student to the problems arising when several shaping circuits are connected together in cascade.

MATERIAL REQUIRED

1. Triode Limiter Chassis.
2. Differentiator-Integrator Chassis.
3. Parallel Diode Limiter Chassis.
4. Bias Supply Chassis.
5. Five-inch oscilloscope with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

In radar equipments, it is frequently necessary to convert a sine wave into a series of narrow, accurately timed pulses. These pulses may be used to start a sequence of operations (in which case they are called "timing pulses"); to furnish adjustable calibration marks ("marker pulses") for display upon the scope screen; or for various other purposes.

This EXPERIMENT will show one method of producing pulses that are spaced with considerable accuracy. It will also acquaint the student with some of the routine difficulties encountered when several units are connected together to form a chain. The next EXPERIMENT will deal with the correction of such difficulties.

PROCEDURE

The Overdriven Amplifier

1. Connect the equipment as shown in figure 1.

2. Observe the waveform being produced by the a-f oscillator. Record this waveform at A in figure 2.

3. Connect the oscilloscope to the output of the triode limiter, and adjust the limiter so that it will operate as an overdriven amplifier. Amplify the output of your signal generator with the AF voltage amplifier chassis, if necessary, to obtain the square wave. Obtain the instructor's approval of the output waveform, then record it as B in figure 2.

Instructor's initials________

The Differentiator

1. Calculate a set of values for C and R in the Differentiator Chassis. Remember that for good differentiation, the following considerations must be observed:

a. The RC time constant must be very short, as compared with the period of the waveform to be differentiated.

b. R must be large, as compared with the plate load resistance of the preceding stage, in order to avoid loading the driving circuit.

Obtain the instructor's approval of your choice of values.

Instructor's initials________

2. Insert in the Differentiator Chassis the RC combination you have chosen.

3. Observe the waveform appearing at the output of the Differentiator Chassis, and record it at C in figure 2.

The Parallel Diode Limiter

1. Set up the Parallel Diode Limiter Chassis to produce only positive pulses at the OUTPUT jack. (Refer to the EXPERIMENT on the parallel diode limiter.)

2. Observe the waveform appearing at the OUTPUT jack, and record it at D in figure 2.

3. Set up the Parallel Diode Limiter Chassis to produce only negative pulses.

4. Observe the waveform appearing at the OUTPUT jack, and record it at E in figure 2.

5. Measure the time in microseconds that elapses between two successive negative pulses at the output of the Parallel Diode Limiter Chassis. (Refer to the INFORMATION SHEET on time measurements by means of a linear sweep.)

________microseconds

6. Measure the width of the pulses (at the base line) in microseconds.

________microseconds

7. Adjust the negative pulses to an amplitude of 10 volts, peak. (Refer to the INFORMATION SHEET on the measurement of non-sinusoidal voltages.) Ask the instructor to check your adjustment.

Instructor's initials________

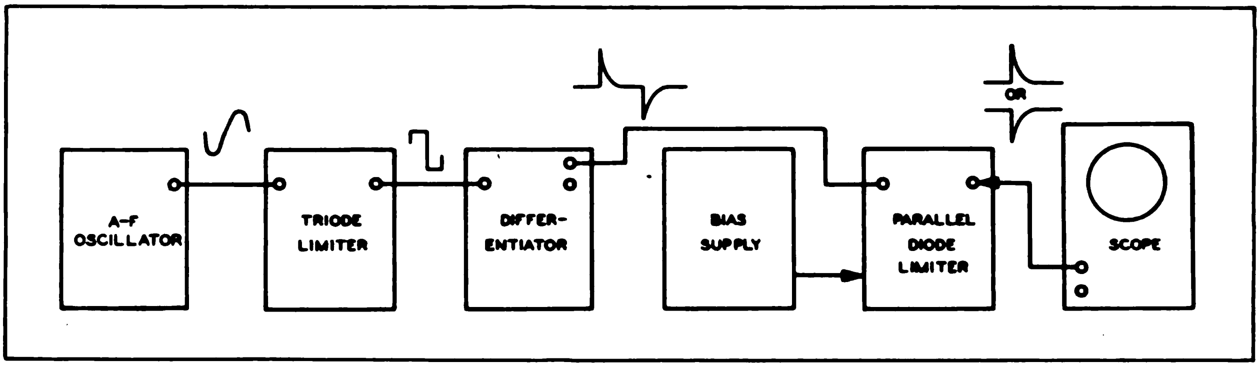
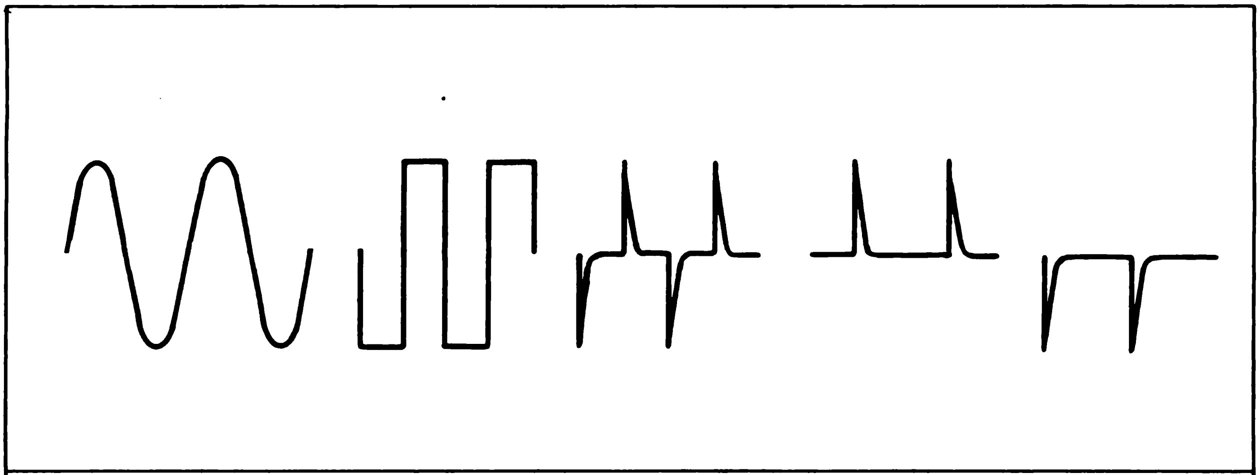


Figure 1. Block Diagram of the Wave-Shaping Chain



A
Input Waveform

B
Output of
Overdriven Amplifier

C
Output of
Differentiator

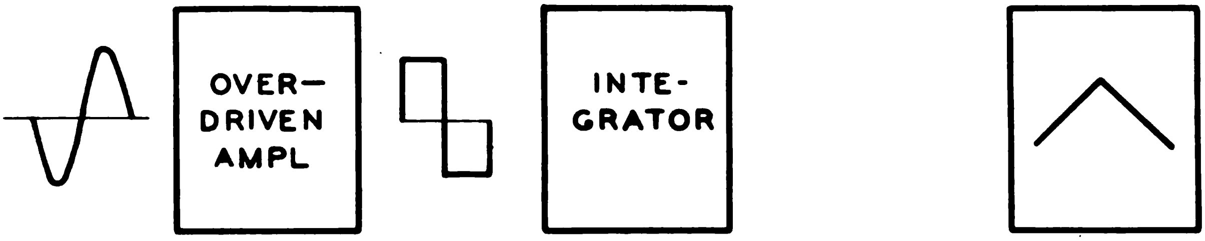
D
Positive Pulses from
Diode Limiter

E
Negative Pulses from
Diode Limiter

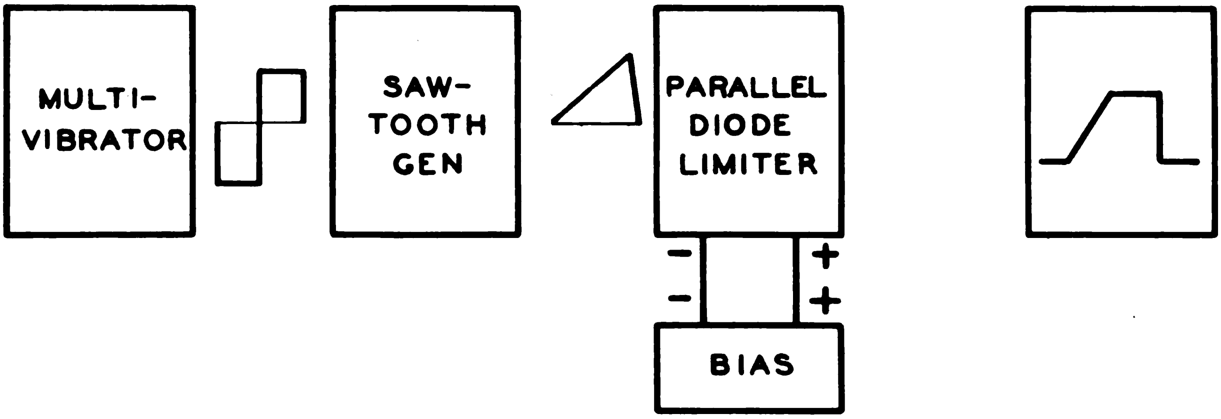
Figure 2. Typical Waveforms Encountered in Wave-Shaping Circuits

CONCLUSIONS

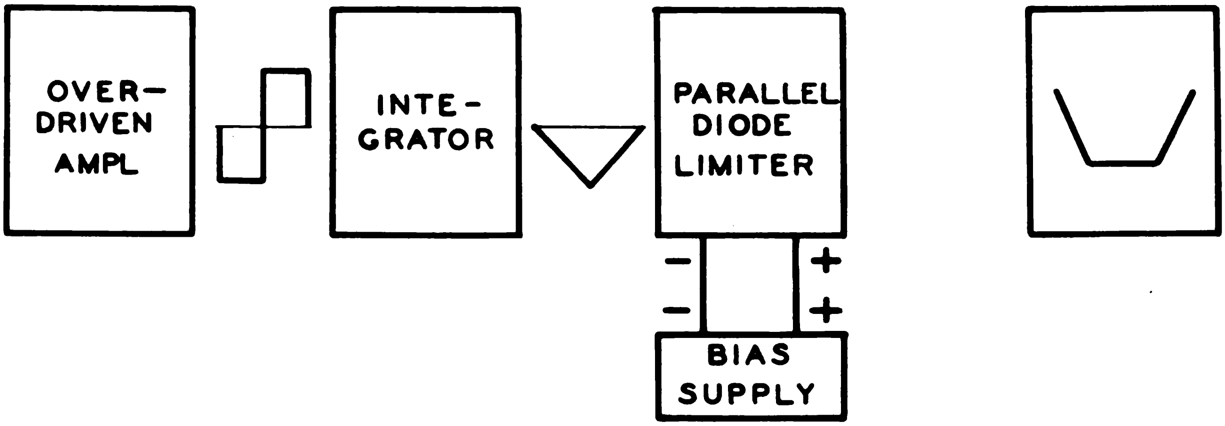
1. Draw a block diagram of a wave-shaping chain capable of converting a sine wave into the waveform shown in the square below. Show the input and output voltage waveforms for each stage.



2. In the same way, draw a block diagram of a chain that will convert a sine wave into the waveform shown in the square below.



3. Draw a block diagram of a chain that will convert a sine wave into the waveform shown in the square below.



LABORATORY PLAN No. 15

SUBJECT

Trouble shooting a wave-shaping chain.

OBJECTIVE

To assist the students in developing and using a step-by-step procedure for locating and removing trouble in a typical radar wave-shaping chain.

MATERIAL REQUIRED

1. Triode Limiter Chassis.
2. Differentiator-Integrator Chassis.
3. Parallel Diode Limiter Chassis.
4. Five-inch oscilloscope with leads.
5. Laboratory Chassis Mounting Rack.
6. Power Supply Chassis.
7. A-F Oscillator with leads.
8. Vacuum-tube voltmeter with leads.

INTRODUCTION

Trouble shooting, if approached in a haphazard way, can be a long and arduous process. If a logical, methodical approach is used, servicing time will be consistently shortened. A logical method of trouble shooting consists of localizing the trouble to a section of the equipment, isolating it to a stage, and then locating the defective part.

SUBJECT MATERIAL

1. Have the students set up the wave-shaping chain as was done in the previous EXPERIMENT, except that the Bias Supply Chassis is not to be used.

2. After a team has demonstrated that its chain is operating properly, insert troubles in the chains, and have the students locate them by a logical trouble-shooting method. As many troubles should be inserted as they can find in the allotted time. The students will fill out a separate JOB SHEET for each group of troubles inserted. The instructor should enter on each JOB SHEET the time required for clearing of the trouble, and such other notes as he may judge desirable, as an aid in grading the EXPERIMENT.

3. The student will prepare a step-by-step trouble-shooting procedure for this chain, using the standard method.

4. After each step, the instructor should check the student's work. He should lead the student, by a series of questions, to think out his problem for himself. Students should not be given ready-made answers; neither should they be left to flounder helplessly, or to adopt haphazard trouble-shooting methods.

5. Near the end of the period, the instructor should hold a blackboard discussion in which he reviews some of the successful case histories he has observed during this laboratory period.

6. During a following laboratory period, after the trouble-shooting charts have been turned in and graded, call upon one or more students to teach the rest of the class how to use the chart(s) that student (or students) prepared. See step 4 under CONCLUSIONS in the accompanying EXPERIMENT.

CONCLUSIONS

A logical, methodical trouble-shooting system reduces the work and the time consumed in repairing electronic devices. The trouble-shooting method used in this EXPERIMENT is such a system.

EXPERIMENT No. 15

SUBJECT

Trouble shooting a wave-shaping chain.

OBJECTIVE

To develop and use a step-by step procedure for locating and removing trouble in a typical radar wave-shaping chain.

MATERIAL REQUIRED

1. Triode Limiter Chassis.
2. Differentiator-Integrator Chassis.
3. Parallel Diode Limiter Chassis.
4. Five-inch oscilloscope with leads.
5. Laboratory Chassis Mounting Rack.
6. Power Supply Chassis.
7. A-F oscillator with leads.
8. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

The wave-shaping chain to be used in this EXPERIMENT is identical with the one whose operation was analyzed in the preceding EXPERIMENT, except that the Bias Supply Chassis is not to be used.

The instructor will place faults in the equipment, and the student will remove them. Then, using the knowledge of trouble-shooting methods he has already acquired, he will compile a complete step-by-step table suitable for teaching others the method of trouble-shooting this chain.

The methods used in locating faults in a pulse chain differ from the methods used in trouble-shooting a radio system chiefly in that more careful attention must be paid to the frequency and waveform as well as the amplitude of the signals at the input and output circuits of various stages. The student will have occasion to refer to his notes on the trouble-shooting of radio equipment, and to the tables compiled during previous radar experiments in which he tabulated the correct operating voltages, resistances and signal voltages in radar Laboratory Chassis which were operating properly.

PROCEDURE

1. Set up the wave-shaping chain shown in the accompanying block diagram. Use the same circuit constants and voltage-divider network employed in the preceding EXPERIMENT on the analysis of a wave-shaping chain.

2. Obtain the instructor's approval of the chain's operation.

Instructor's initials_______

3. The instructor will now insert faults into the chain. He will also make suitable entries on the attached JOB SHEET, for use in grading the EXPERIMENT.

4. Using a logical method of trouble-shooting, localize the trouble to one section of the chain; isolate it to one particular circuit; and locate the faulty component. All this work must be performed in a logical step-by-step fashion—not by the random replacement of parts.

5. Keep a complete set of notes on your procedure, giving the following information:

a. The symptoms observed.

b. The test points used and the tests performed to localize the trouble to one particular section of the chain, and the results obtained.

c. The test points used and the tests performed to isolate the trouble to one particular circuit in the faulty section, and the results obtained.

d. The test points used and the tests performed to locate the faulty component of the defective circuit, and the results obtained.

e. Any complications noted during the trouble-shooting process.

6. After you have corrected the faults, obtain the instructor's approval of the chain's operation. Then enter the information compiled in step 5, above, on the JOB SHEET.

Instructor's initials______

7. If time permits, ask the instructor to insert other faults in the chain. Clear them in the manner outlined above, and make out another JOB SHEET. Additional credit for this EXPERIMENT will be given if more than one JOB SHEET is completed.

CONCLUSIONS

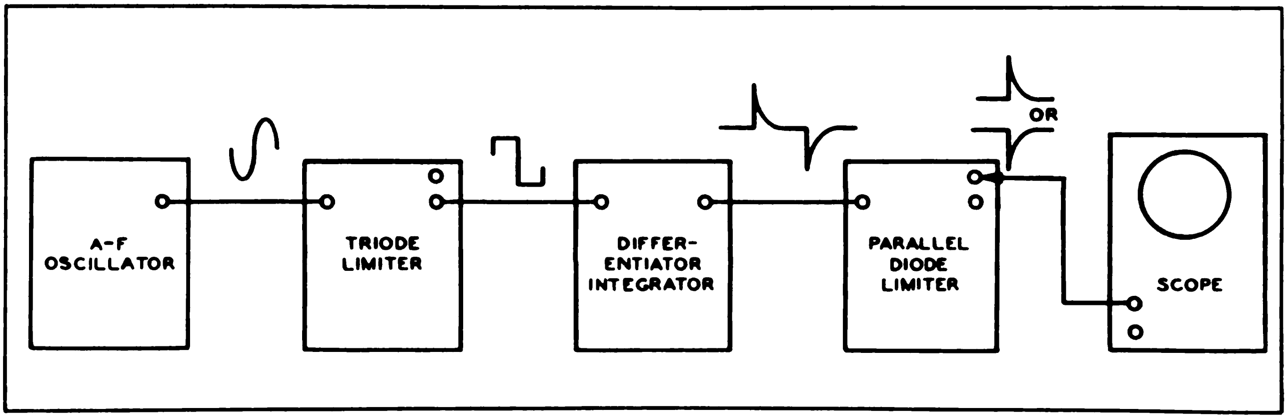
Using the data compiled and the experience gained in this EXPERIMENT, prepare a step-by-step trouble-shooting procedure for this chain, as below. Use the standard trouble-shooting method.

1. Draw a large-scale schematic diagram of the entire chain, including the power supply.

2. Indicate all test points to be used, classifying them as Major Test Points, Key Test Points, and Secondary Test Points.

3. Make up a typical trouble-shooting chart for this wave-shaping chain. This chart will be used later as a model for compiling a complete trouble-shooting chart for the entire laboratory radar system.

4. Be prepared to discuss your trouble-shooting chart in class, presenting the method as you would explain it if you were teaching a class in radar maintenance. One or more of the charts will be selected at random by the instructor, and the student who prepared the chart will be asked to teach his trouble-shooting method to the rest of the class.



Block Diagram of the Wave-Shaping Chain

JOB SHEET

STUDENT'S NAME____

SECTION____

INDICATION (no output, distortion, hum pickup, etc.)

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE WAVE-SHAPING CHAIN.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)

LABORATORY PLAN No. 16

SUBJECT

The diode clamper.

OBJECTIVE

To assist and supervise the class in the testing of a Diode Clamper Chassis.

MATERIAL REQUIRED

1. Diode Clamper Chassis.
2. Square Wave Generator Chassis.
3. Cathode Follower Chassis.
4. Bias Supply Chassis.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.
8. Voltage Tripler Chassis.
9. Oscilloscope Chassis.

INTRODUCTION

Generally, a clamping circuit (commonly referred to as a d-c restorer) is one which maintains either the negative or positive peaks of a waveform at some reference level of voltage. Such circuits are frequently used in radar, television, and any other system where it is necessary to insure that sweep voltages always start from the same reference level.

SUBJECT MATERIAL

1. Give a brief demonstration to the class, familiarizing them with the Diode Clamper Chassis and the individual parts, as was done in previous EXPERIMENTS.

2. Explain to the class that proper operation of the circuit requires direct connection to the horizontal and vertical deflecting plates of the oscilloscope without the use of a coupling capacitor.

3. Show how the scope chassis can be so connected.

4. Conduct a brief demonstration, pointing out the results to be expected in the operational section of the EXPERIMENT, and following the steps given there.

5. Be sure that each student fills out his workbook as the EXPERIMENT progresses.

CONCLUSIONS

In magnetic-deflection circuits, clamping action is used at the grids of sweep amplifiers. The clamper circuit insures that the sweep voltages, and consequently the traces, always start from the same reference point, thus eliminating jittery or erratic operation.

EXPERIMENT No. 16

SUBJECT

The diode clamper.

OBJECTIVE

To test a Diode Clamper Chassis suitable for use in connection with a radar indicator (oscilloscope); to study the circuit used in a typical clamper; to observe the effects of negative clamping and positive clamping, both at zero and at potentials other than zero, upon both the vertical and the horizontal deflection.

MATERIAL REQUIRED

1. Diode Clamper Chassis.
2. Square Wave Generator Chassis.
3. Cathode Follower Chassis.
4. Bias Supply Chassis.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.
8. Voltage Tripler Chassis.
9. Oscilloscope Chassis.

INSTRUCTIONS

Clamper circuits (also known as d-c restorers and base-line stabilizers) are useful in many radar equipments, where they are employed to eliminate jitter, and to center one end of a sweep line that is to be rotated around the scope face like a moving vector (as in the case of the plan-position indicator, to be studied later).

The correct operation of clamper circuits requires direct connection to the oscilloscope deflection plates, without interposing a coupling capacitor.

The cathode follower is placed between the square-wave generator and the clamper, in order to reduce the amplitude of the input signal to a point where the entire signal can be displayed on the scope screen. If the follower were not used, the high-voltage signal from the square-wave generator would drive the square wave completely off the screen at both the top and the bottom. The amplitude of the cathode-follower output can be controlled by changing the size of the cathode load resistor.

PROCEDURE

Clamping at Zero

1. Set up the equipment as indicated in the block diagram, figure 1. Adjust bias to zero.

2. Adjust the square-wave generator to produce symmetrical square waves.

The Unclamped Waveform

1. Remove SS-1 and SS-1 ALT. from the Diode

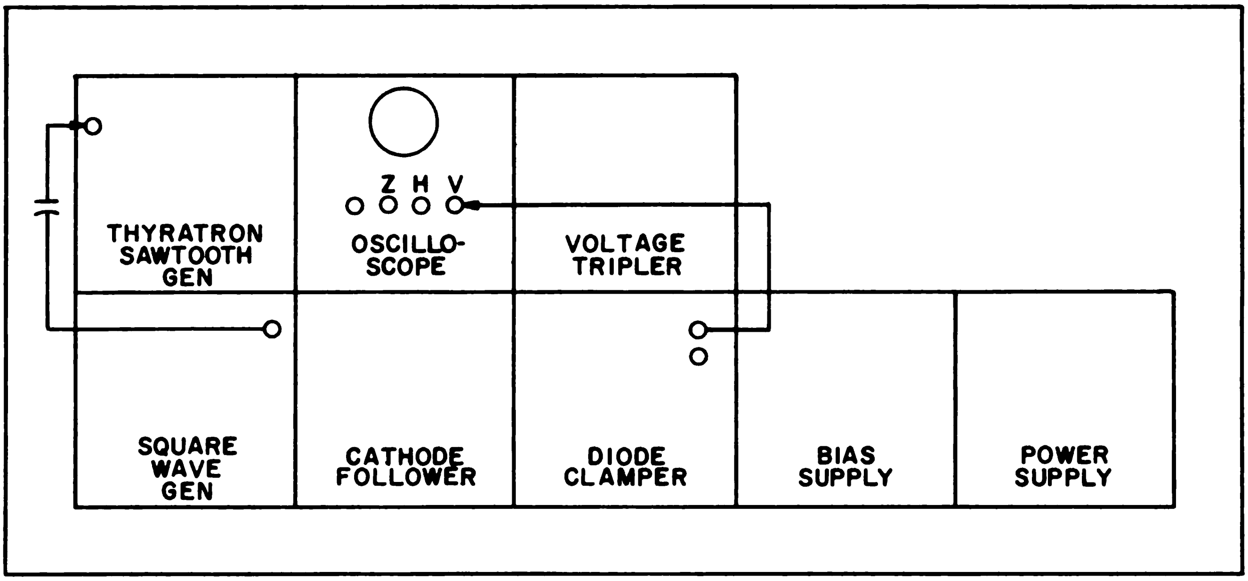


Figure 1. Block Diagram of Equipment Setup for the Diode Clamper Experiment

Clamper Chassis. This disables the clamper. The waveform appearing on the scope screen swings positive and negative around a horizontal "zero voltage" line through the center of the waveform.

2. Sketch the observed waveform at A in figure 2, being careful to place it symmetrically above and below the horizontal center line.

Negative Clamping

1. Insert SS-1 and SS-2, and observe that the trace moves downward until its top rests along what was formerly its center line. This is called negative clamping at zero, since the trace is negative at all times except when it falls to zero.

2. At B in figure 2, sketch the waveform observed.

Positive Clamping

1. Place SS-1 in its alternate position. Observe that the trace moves upward until the bottom of the trace falls along what was originally the center line. This is called positive clamping at zero, since the trace is positive at all times except when it falls to zero.

2. At C in figure 2, sketch the waveform observed.

Clamping at Potentials Other Than Zero

1. Insert SS-1 in its normal position and SS-2 in its alternate position. Place SS-1 of the Bias Supply Chassis in its alternate position.

2. Turn the negative bias control knob of the Bias Supply Chassis from its fully counterclockwise position to its fully clockwise position and observe the change that occurs in the scope trace. Describe this change in the space provided below.

3. At A in figure 3, sketch the position of the waveform obtained with negative bias.

4. Place SS-1 of the Clamper in its alternate position. Connect SS-1 of the Bias Supply Chassis in its normal position.

5. Turn the positive bias control knob of the Bias Supply Chassis from its fully counterclockwise position to its fully clockwise position and observe the change that occurs in the scope trace. Describe this change in the space provided at right above.

6. At B in figure 3, sketch the position of the waveform obtained with a positive bias.

CONCLUSIONS

1. Why is a clamper used in some radar circuits?

A clamper is used in radar circuits to clamp, or hold, the starting point of the sweep so that the trace will originate at the same point each time. This minimizes jitter.

2. Explain in detail the operation of the clamper circuit shown at A in figure 3.

The waveform is clamped to a negative potential. On positive alternations, the capacitor is charged through the resistor and the tube; but since the resistance of the tube is low, only a short positive pip is developed across the output. Just enough current flows into the capacitor to replace the charge it lost during the preceding half-cycle, by leakage to ground through the resistor. Except for this very slight pip (which may not even be visible on a scope), the output voltage is held at the level of the negative bias voltage during the positive peaks of the input wave. On negative alternations, the capacitor slowly discharges through the resistor, developing a negative voltage drop. On the following positive alternation, the charge is restored to the capacitor, and the cycle repeats itself. The output is at the same amplitude as the input.

3. Explain in detail the operation of the circuit shown at B in figure 3.

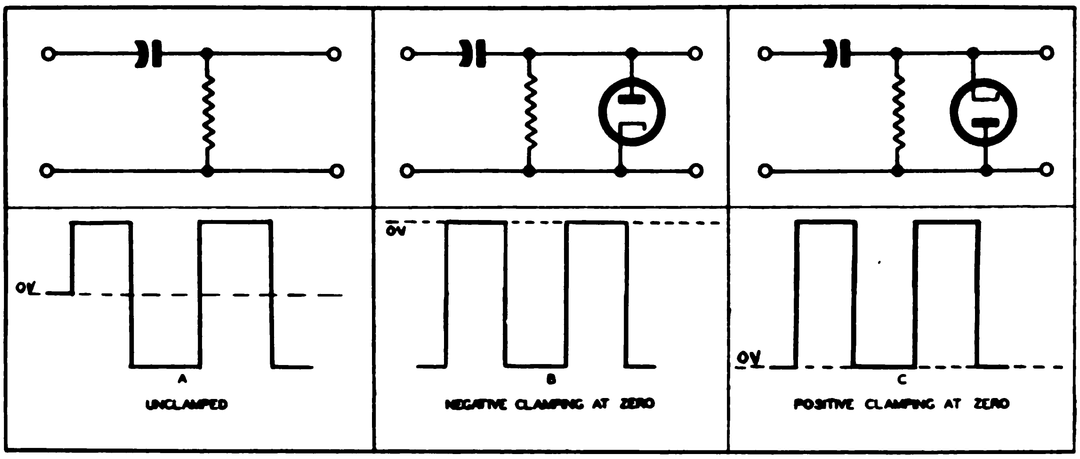


Figure 2. Waveforms Obtained with and without Clamping

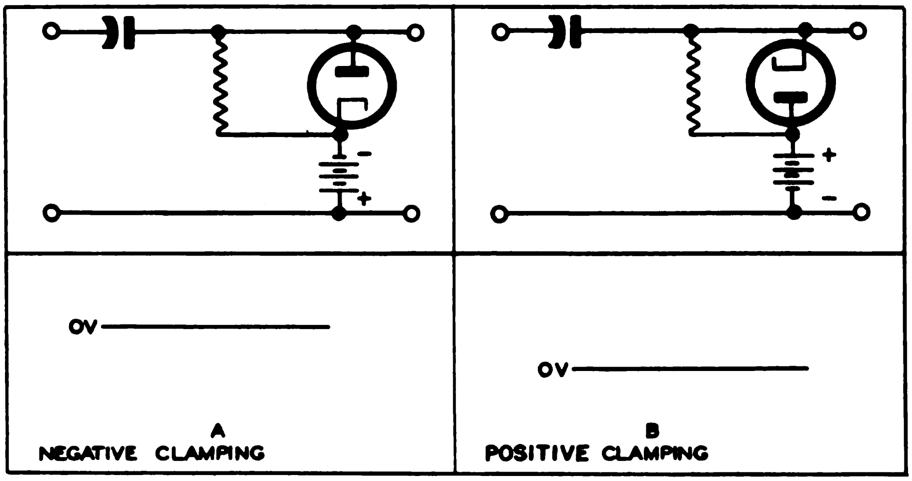
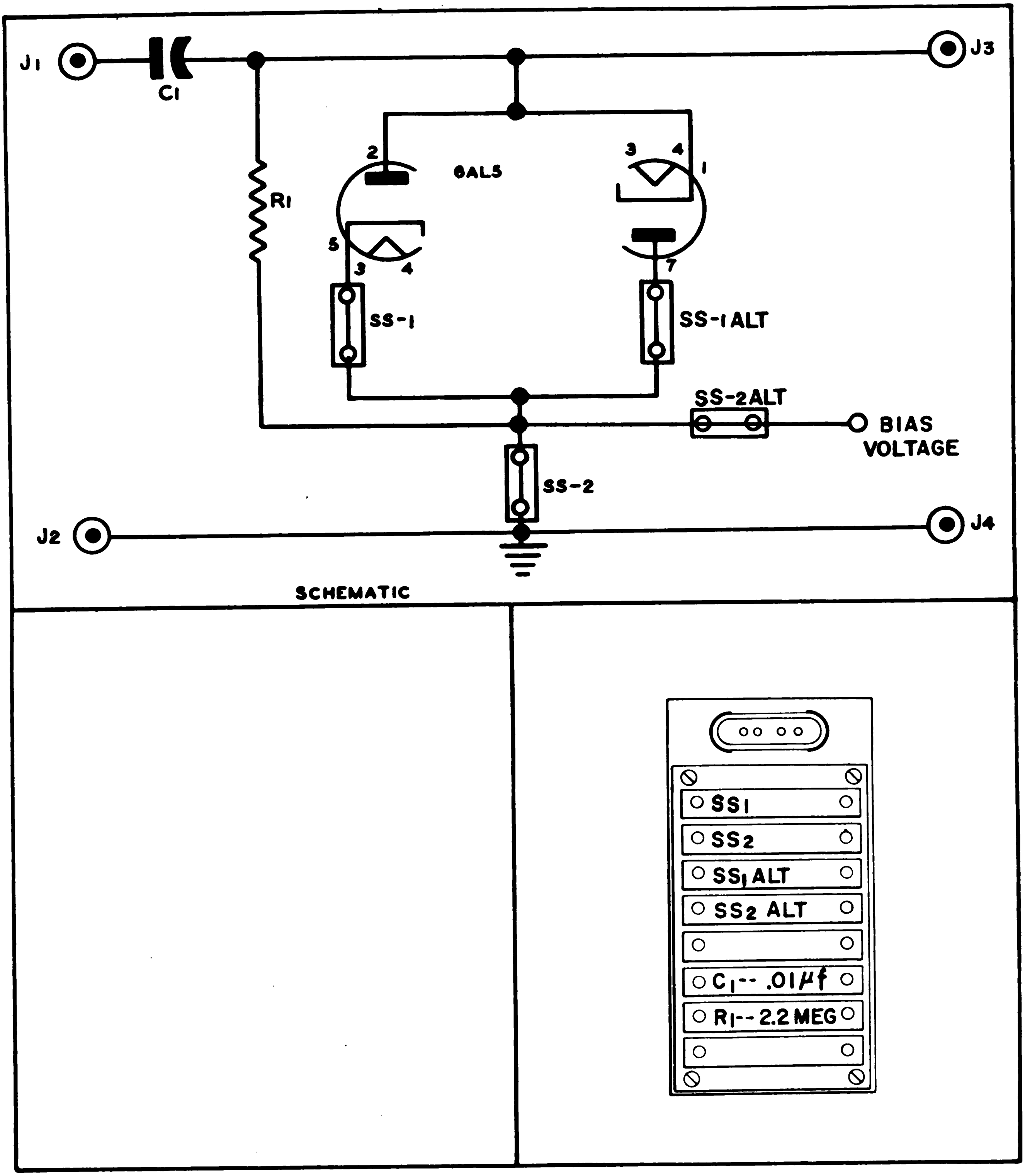


Figure 3. Waveforms Obtained When Clamping Above and Below Zero



Schematic Diagram of Diode Clamper Chassis

LABORATORY PLAN No. 17

SUBJECT

The Eccles-Jordan trigger circuit.

OBJECTIVE

To familiarize the student with the operation of the Eccles-Jordan trigger circuit and some of its uses.

MATERIAL REQUIRED

1. Eccles-Jordan Trigger Circuit Demonstration Unit.
2. Single-Swing Blocking Oscillator Demonstration Unit.
3. Audio Voltage Amplifier Demonstration Unit.
4. Power Supply Demonstration Unit.
5. Vacuum-tube voltmeter with leads (2 required).
6. Five-inch oscilloscope with leads.
7. Additional plug-in resistor, 470,000 ohms (2 required).

REFERENCES

Lecture notes taken during class.

INSTRUCTIONS

See INSTRUCTIONS in experiment.

SUBJECT MATERIAL

1. Draw on the blackboard the circuit of the Eccles-Jordan trigger circuit. Include all labels and values. Allow enough time for the students to copy this diagram in their notes before proceeding. (NOTE: Refer to the instructor's copy of this EXPERIMENT to obtain this schematic diagram.)

2. Give the class a preliminary explanation of the circuit operation. Specify that the circuit requires a trigger pulse to produce a square-wave output, that cutoff is produced in one tube when the other tube conducts; and that either a positive or a negative pulse can trigger the circuit. Refer to the EXPERIMENT to obtain information concerning the effect of trigger pulses on the circuit.

3. Using the Eccles-Jordan Demonstration Unit, make the d-c voltage measurements specified in the table attached to the EXPERIMENT, and have the students record these values.

4. Explain how one tube can remain conducting and the other cut off, and how it is possible to reverse these conditions at will. Refer to the appropriate section in the EXPERIMENT for this explanation.

5. Apply a recurrent trigger pulse to the circuit, and allow the circuit to "flip-flop" at a frequency high enough to permit viewing the voltage waveform on the scope. When a positive trigger is applied, an audio amplifier circuit must usually be used between the single-swing blocking oscillator and the Eccles-Jordan trigger circuit. This is not required when a negative trigger pulse is applied. The block diagrams of the equipment setup are given in the EXPERIMENT.

6. Measure the average d-c voltages developed at various points in the circuit, as outlined in the table. Allow enough time between each measurement to permit each student to record your readings.

7. Remove the coupling capacitors from the circuit. Show the class that oscillations either become erratic or cease altogether. Explain why this occurs.

8. Replace the coupling capacitors, and apply a recurrent trigger pulse to the Eccles-Jordan trigger circuit. Display the waveforms developed on the oscilloscope. Construct a synchrogram of these waveforms on the blackboard (refer to the appropriate section in the EXPERIMENT), so that the students may copy the waveforms in their notes.

9. Apply, in order, a positive, a negative, and an alternately positive and negative trigger pulse to the Eccles-Jordan circuit. Explain the results as they occur.

10. Call to the attention of the class the fact that there is a minimum amplitude of trigger pulse that will produce consistent triggering of the Eccles-Jordan circuit. Point out that the minimum amplitude for a positive trigger pulse is not the same as that for a negative trigger pulse. Explain this fact, referring to the explanation given in the EXPERIMENT.

CONCLUSIONS

Conclude this demonstration with a summary, emphasizing the important aspects of the circuit. This is best shown by an equivalent circuit. Point out such things as the "flipped" and "flopped" conditions of the circuit, the necessity of coupling capacitors, the amplitude of the trigger pulses, and so forth.

EXPERIMENT No. 17

SUBJECT

The Eccles-Jordan trigger circuit.

OBJECTIVE

To become familiar with the operation of the Eccles-Jordan trigger circuit and some of its uses.

REFERENCES

Lecture notes taken during class.

INSTRUCTIONS

This EXPERIMENT will be in the form of a laboratory demonstration, performed by the instructor. The voltage measurements and waveforms developed during this demonstration are to be recorded in the table attached to this EXPERIMENT. The student will also be held responsible for a complete set of notes on the diagrams, analyses, and explanations given by the instructor during this demonstration.

The Eccles-Jordan trigger circuit is widely used as a means of turning radar chains on and off, and of introducing delay into such operations. It will be shown that this circuit is essentially a multivibrator that requires a trigger pulse to start each half of its cycle of operation. A study will be made of the d-c voltage conditions existing in the circuit when triode No. 1 is conducting and triode No. 2 is cut off; when the condition is reversed, with triode No. 2 conducting and triode No. 1 cut off; and when the circuit is being triggered by a recurrent trigger pulse.

PROCEDURE

Circuit Diagram

1. Copy the circuit diagram of the Eccles-Jordan trigger circuit, which the instructor will draw on the blackboard. Include all labels and values.

2. Make a set of notes on the preliminary explanation of the circuit operation which will be given by the instructor.

The Eccles-Jordan circuit requires a trigger pulse to produce a square wave output. Cutoff in one tube is produced by the conduction of the other tube. A positive or negative pulse can trigger the Eccles-Jordan circuit. A positive pulse triggers the circuit by causing the cutoff tube to conduct; a negative pulse triggers the circuit by decreasing the current flow through the conducting tube, causing the other tube to conduct.

D-C Voltage Measurements

1. In the accompanying table, record the values of d-c voltage measured at various points throughout the circuit when one tube is conducting and the other is cut off.

2. Record in the table the values of d-c voltage measured at the same points in the circuit when the tube that was originally conducting is cut off, and the tube that was originally cut off is brought into conduction.

3. On the circuit drawing, copied in the first step of this demonstration, enter the data recorded in the table.

4. In view of these measured voltages, why is it possible to maintain one tube in a conducting condition while the other tube is cut off, or to reverse these conditions at will?

The current through the conducting tube flows through a voltage-divider network. The nonconducting tube is biased beyond cutoff by a voltage selected from this divider. A trigger pulse will either decrease the current through the tube that is conducting (if the pulse is negative), or start current flow in the other tube (if the pulse is positive). If current flow through the conducting tube is decreased, the bias of the other tube decreases, and current flow starts. This biases the first tube, decreasing current flow still more. This action is highly regenerative, and continues until the second equilibrium condition is reached.

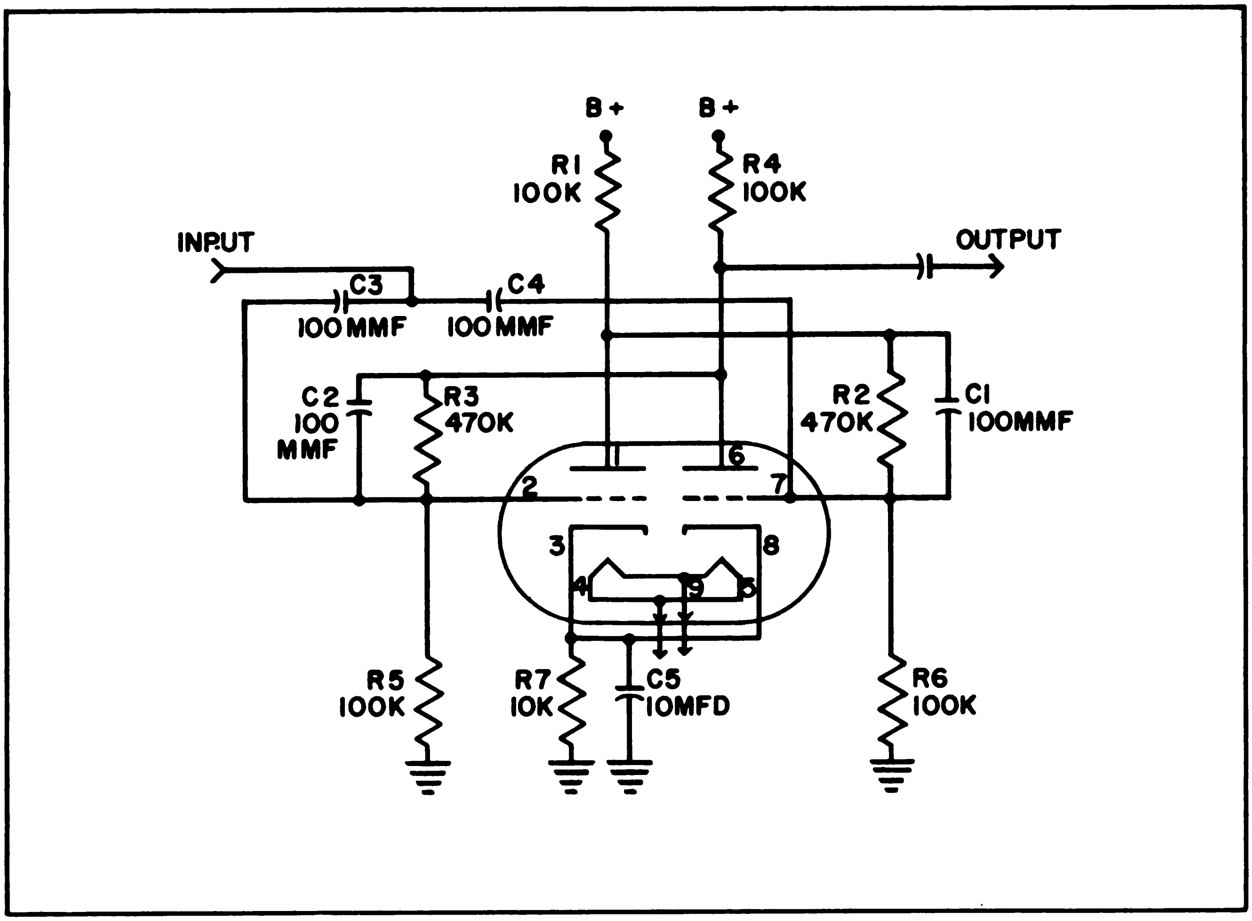
Triggered Operation

1. The instructor will now apply a recurrent trigger pulse to the circuit, and cause the circuit to "flip-flop" at a frequency high enough to permit viewing the voltage waveform on the scope. In the space provided below, draw a block diagram of the equipment used in this setup.

2. The instructor will now remove the coupling capacitors from the circuit. It will be observed that oscillation now becomes erratic, or ceases altogether. In the space provided below, copy the instructor's explanation of this phenomenon.

Waveforms

1. The instructor will display on an oscilloscope the waveforms developed in the Eccles-Jordan circuit when the coupling capacitors are restored and a recurrent trigger pulse is applied



Eccles-Jordan Trigger Circuit

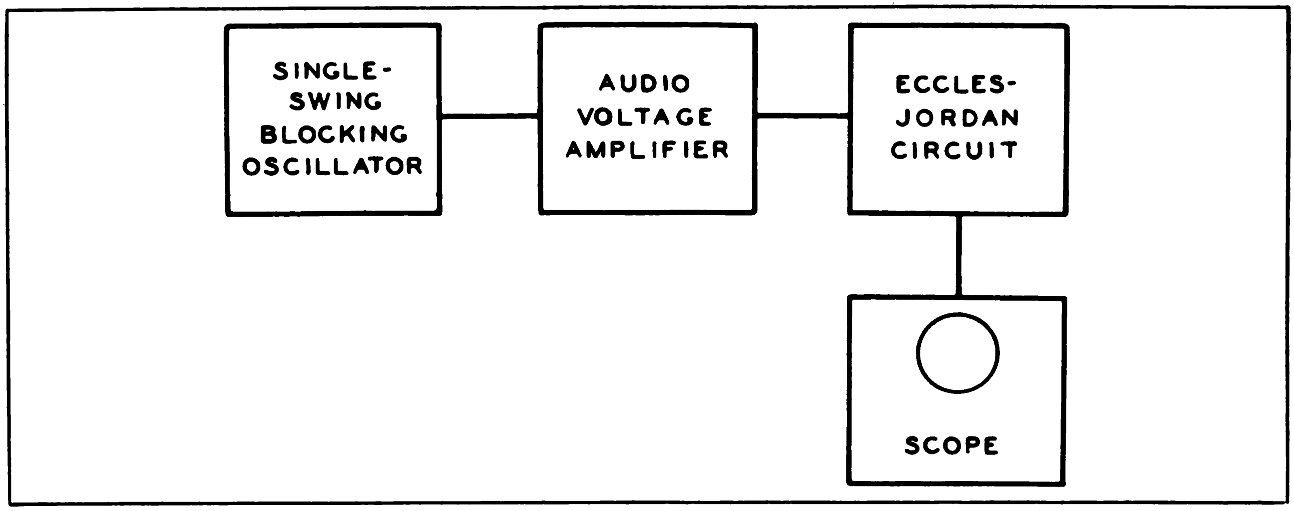
to the circuit. In the space provided, construct a synchrogram of these waveforms, being careful to show them in proper phase relationship with each other.

2. The effect of positive triggers, negative triggers, and triggers that are alternately positive and negative will be demonstrated. In the space provided below, note the instructor's explanation of the results.

All the pulses, if of sufficient amplitude, trigger the circuit. The positive pulses trigger because they drive the non-conducting tube into operation. The negative pulses decrease current flow in the conducting tube, which drives the non-conducting tube into operation.

3. Note that there is a minimum amplitude of trigger pulse that will produce consistent triggering of the Eccles-Jordan circuit. Note also that the minimum amplitude for a positive pulse is not the same as the minimum amplitude for a negative pulse. Record the explanation given by the instructor.

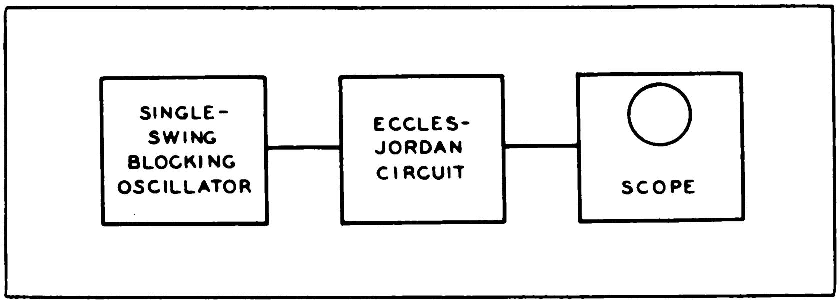
A positive pulse, to trigger the circuit, must be large enough to drive the non-conducting tube into conduction. The minimum negative pulse need not be this large. A negative pulse decreases plate current, which decreases the bias on the non-conducting tube. The pulse coupled from the plate must be large enough to drive the non-conducting tube into conduction. But the conducting tube is an amplifier and the pulse from the plate (which must be as large as the minimum positive triggering pulse) will be much larger than the original negative trigger.



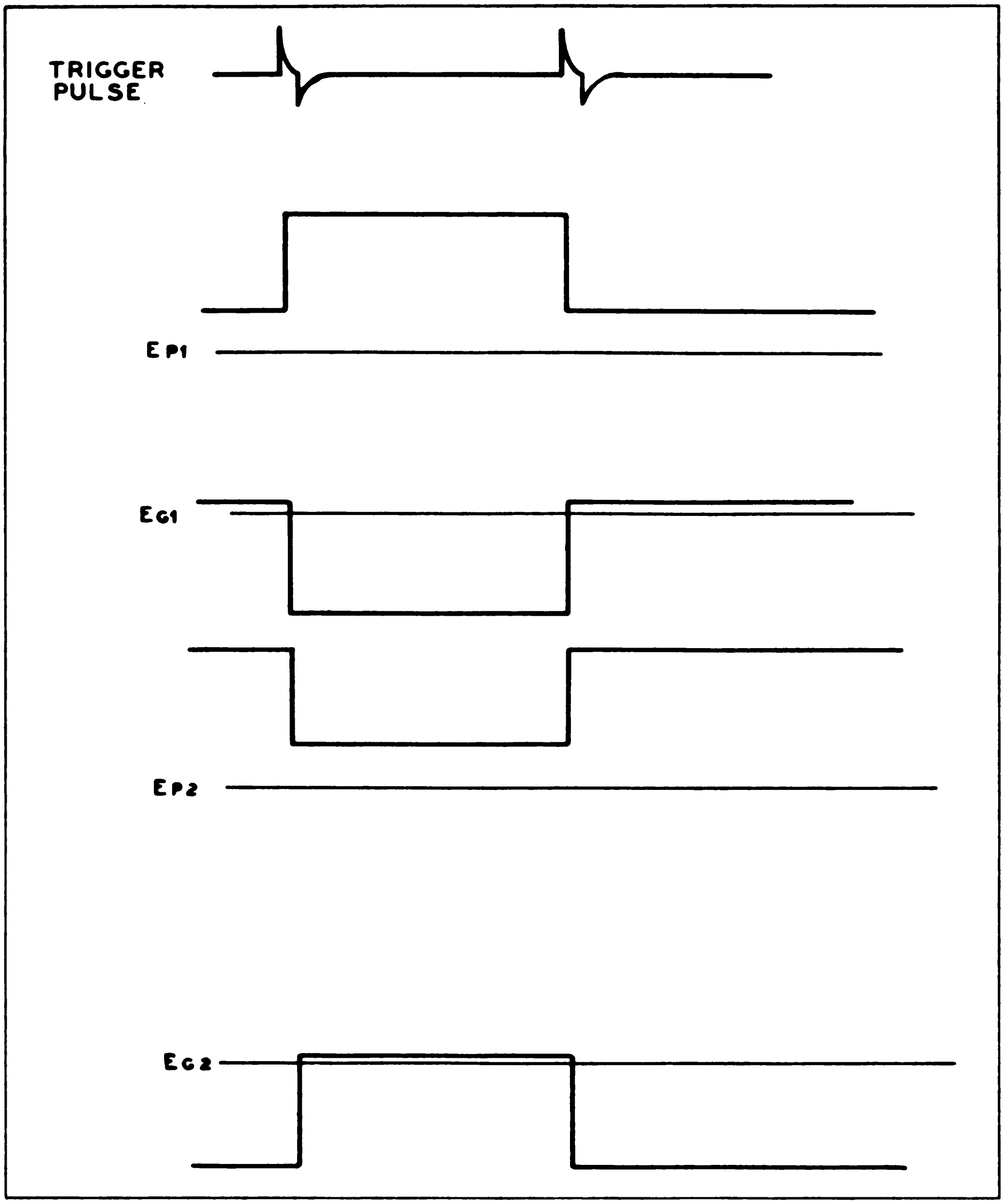
Block Diagram of Equipment Setup for Positive Trigger

CONCLUSIONS

Summarize the facts brought out by this DEMONSTRATION, placing special emphasis upon the circuit diagram; the reason for the circuit remaining either "flipped" or "flopped" between trigger pulses; the necessity for using coupling capacitors; and the approximate amplitude of the trigger pulse required, both positive and negative. Give the reason for the difference in these required trigger amplitudes.



Block Diagram of Equipment Setup for Negative Trigger



Synchrogram of Waveforms Developed in the Eccles-Jordan Circuit

TABLE OF VOLTAGES AND CURRENTS IN THE ECCLES-JORDAN CIRCUIT, UNDER VARIOUS CONDITIONS

VOLTAGE DROP ACROSS	FUNCTION OF RESISTOR	RESISTANCE VALUE (Ohms)	WITH TUBE V1A CONDUCTING CONTINUOUSLY		WITH TUBE V1B CONDUCTING CONTINUOUSLY	
			Voltage (volts)	Calculated Current (ma)	Voltage (volts)	Calculated Current (ma)
R1						
R3						
R6						
R4						
R2						
R5						
R7						

LABORATORY PLAN No. 18

SUBJECT

The single-swing blocking oscillator.

OBJECTIVE

To supervise the testing of a blocking oscillator, and to aid the student in making measurements on this generator, in order to familiarize him with its waveforms and its capabilities.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis.
2. Vacuum-tube voltmeter with leads.
3. A-F oscillator with leads.
4. Five-inch oscilloscope, with leads and cross-section screen.
5. Laboratory Chassis Mounting Rack.
6. Power Supply Chassis.

INTRODUCTION

The single-swing blocking oscillator will be used as a trigger generator. This circuit, like the square-wave generator, has many uses in radar systems. Details of its circuit action will be studied in a later EXPERIMENT.

SUBJECT MATERIAL

1. Exhibit the Single-Swing Blocking Oscillator Chassis to the class, as was done in previous EXPERIMENTS.
2. Check the student's voltage and resistance measurements, and be sure all figures are correct.
3. Show the student the waveform that will be observed with the power applied and the potentiometer at mid-scale.
4. Check the student's measurements of the frequency range, and make sure they are accurate.
5. Insist that all work be submitted for your approval.

CONCLUSIONS

The generator is capable of producing a single swing of audio frequency before it blocks. This swing may be used to trigger other circuits.

EXPERIMENT No. 18

SUBJECT

The single-swing blocking oscillator.

OBJECTIVE

To consider a blocking oscillator as a source of trigger pulses in subsequent EXPERIMENTS; to make tests and measurements on this generator, in order to determine its capabilities and become familiar with the waveforms produced.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis.
2. Vacuum-tube voltmeter with leads.
3. A-F oscillator with leads.
4. Five-inch oscilloscope, with leads and cross-section screen.
5. Laboratory Chassis Mounting Rack.
6. Power Supply Chassis.

INSTRUCTIONS

The trigger generator to be tested in this EXPERIMENT is a useful device of many applications. This circuit, like the square-wave generator, the saw-tooth generator, and the cathode follower, plays an important part in radar systems. The circuit used is that of a single-swing blocking oscillator. Its operation will be studied further in a later EXPERIMENT.

PROCEDURE

Testing

1. *With the tube out of its socket,* make resistance checks, and take voltage readings at the tube-socket terminals.
2. If any improper readings are obtained, locate and correct the trouble, before proceeding.

Operational Checks

1. Place SS-2 in its alternate position. Insert the 6AB4 tube, apply power, and observe the waveform appearing at OUTPUT jack J3 (oscillator plate). Record this waveform at A in figure 1.
2. With the potentiometer set at half-scale, measure, and record at A, the peak positive and negative amplitudes of this wave.

CONCLUSIONS

1. Describe in detail any difficulty encountered in getting the trigger generator to operate properly. Note the symptoms of improper operation, the procedure followed in looking for trouble, the source(s) of trouble discovered, and the corrective measures taken.
2. Refer to any reference books available, and give possible uses for the trigger generator you have just tested. In connection with each use, draw a block diagram of the equipment to be used, and indicate the input and output waveforms of each block. Record the book and page from which this information was obtained.
3. Place SS-2 in its normal position. Observe the waveform obtained at OUTPUT jack J3 (oscillator cathode). Record this waveform at B in figure 1.
4. Measure, and record at B, the peak amplitudes of the cathode-voltage waveform.
5. Set the potentiometer at its maximum-resistance position, and measure the frequency generated.

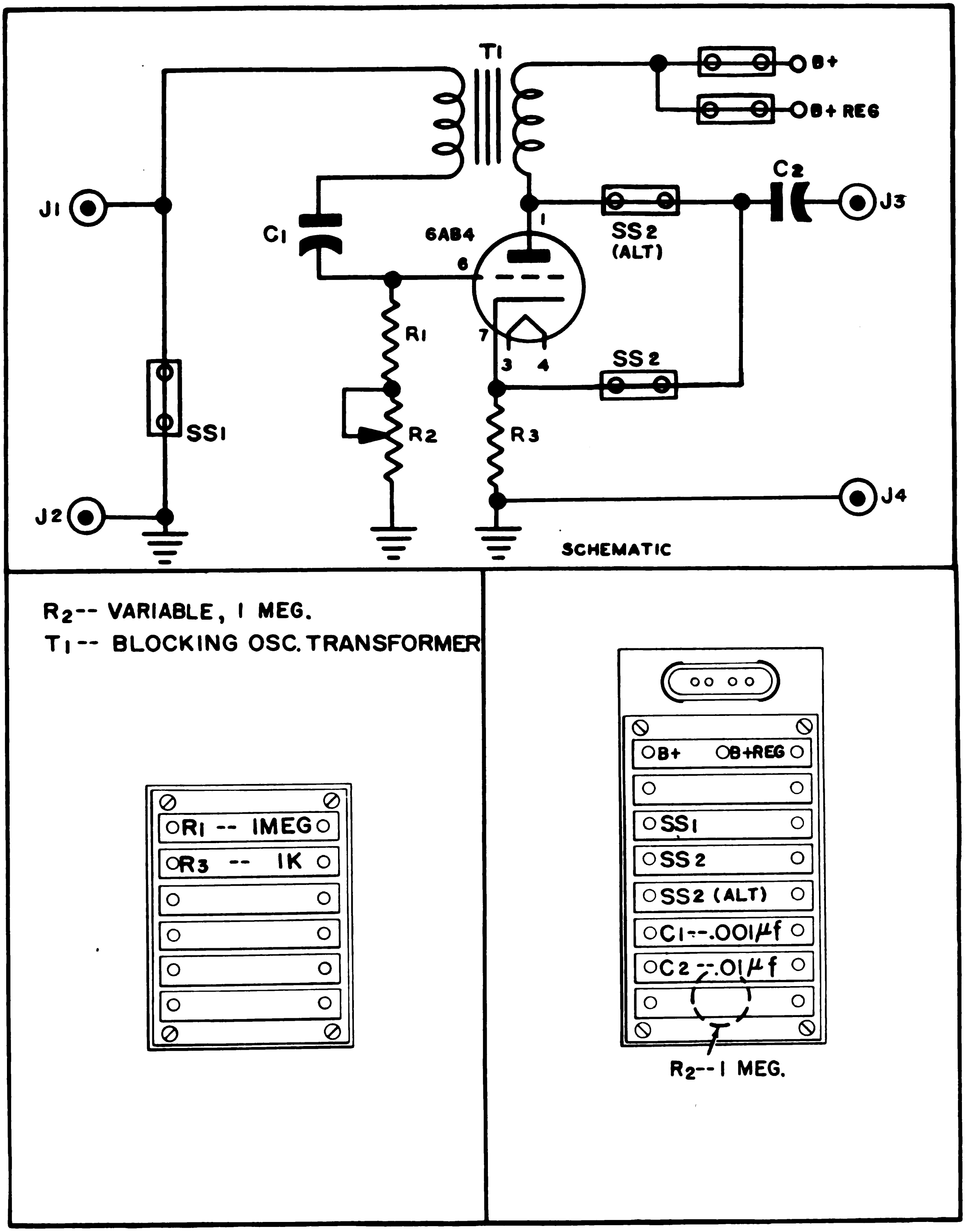
Frequency______cycles

6. Set the potentiometer at its minimum-resistance position, and measure the frequency generated.

Frequency______cycles

A B C

Figure 1. Waveforms Developed in a Single-Swing Blocking Oscillator



Schematic Diagram of Single-Swing Blocking Oscillator Chassis

LABORATORY PLAN No. 19

SUBJECT

The plate-coupled multivibrator.

OBJECTIVE

To explain and demonstrate to the class the operation of this type of oscillator circuit, covering the following points:

1. The waveforms produced.
2. The circuit constants which control the output frequency.

MATERIAL REQUIRED

1. Square Wave Generator Chassis (plate-coupled multivibrator).
2. Cathode Follower Chassis.
3. Laboratory Chassis Mounting Rack.
4. Power Supply Chassis.
5. Five-inch oscilloscope, with leads and cross-section screen.
6. A-F oscillator with leads.
7. Vacuum-tube voltmeter with leads.

INTRODUCTION

The square-wave generator, studied earlier in the course, and is to be used extensively throughout, is identical to the plate-coupled multivibrator. This multivibrator is a type of relaxation oscillator, and is a source of square or rectangular waves; hence, it has important applications in radar.

SUBJECT MATERIAL

1. Require each student to review the circuit analysis of the square-wave generator.
2. Show the class how to connect the chassis directly to the vertical scope plates.
3. Demonstrate to the class the symmetrical waveform which should appear at the output when the circuit is properly adjusted.
4. Have the students follow the procedure in the EXPERIMENT, and check their work for accuracy and completeness.
5. Make certain that all points outlined in the OBJECTIVE have been thoroughly covered, and are completely understood by the student.
6. Be sure the student completes all the requirements in his workbook.

CONCLUSIONS

The student should have, at the completion of this EXPERIMENT, a thorough knowledge of the plate-coupled multivibrator circuit and the waveforms and voltage amplitudes it is capable of producing. The difference between distortion occurring in the oscillator and that occurring in the oscilloscope should be distinguishable to the student. The circuit finds wide application in radar systems, and the student should be familiar with it.

EXPERIMENT No. 19

SUBJECT

The plate-coupled multivibrator.

OBJECTIVE

To study the operation of this type of oscillator; to study the waveforms produced; to determine which circuit constants control the output frequency.

MATERIAL REQUIRED

1. Square Wave Generator Chassis (plate-coupled multivibrator).
2. Laboratory Chassis Mounting Rack.
3. Power Supply Chassis.
4. Five-inch oscilloscope, with cross-section screen and leads.
5. A-F oscillator with leads.
6. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

The next few EXPERIMENTS will be devoted to a study of various types of multivibrators. All of these circuits generate square or rectangular waveforms that find wide application in radar equipment.

The square-wave generator, studied earlier in the course, is identical to a device known as the "plate-coupled multivibrator." The circuit employed in this generator, the waveforms it produces, and the effect of changing its circuit constants will now be studied.

PROCEDURE

1. Fasten the square-wave generator and the power supply in the same row in the rack and turn the equipment on.

Waveforms

1. Connect the scope to the OUTPUT jack J3 of the Square Wave Generator Chassis. This jack connects to the plate of the right-hand triode.
2. At B in figure 1, plot this waveform accurately. Plot microseconds on the horizontal axis, and voltage on the vertical axis. In making the measurements necessary to plot the waveform, use the methods described in the INFORMATION SHEET on time measurements by means of a linear sweep, and in the INFORMATION SHEET on voltage measurements of non-sinusoidal waveforms.
3. Transfer the scope lead to the INPUT jack J1, which is connected to the grid of the left-hand triode. Using the methods described in step 2, observe and record, at C in figure 1, the waveform at this point.
4. Observe and record, at A in figure 1, the waveform appearing at the plate of the left-hand triode. You can obtain this output by connecting to the component strips on the back of the panel.
5. Observe and record, at D in figure 1, the waveform appearing at pin 7 of the multivibrator tube. This pin connects to the grid of the right-hand triode.
6. At figure 2, arrange the waveforms of figure 1 in a vertical column, being careful to place them in proper phase relationship with each other. The proper phase relationship can be determined by referring to your lecture notes. The type of drawing then appearing at figure 2 is known as a "synchrogram," and will be used frequently in out study of pulse generators.

Parts Affecting Frequency

Plate Resistors

1. Use the following plug-in parts in the multivibrator:
   Plate resistors, 100,000 ohms.
2. Measure the frequency of the resulting square waves by comparison with the output of the a-f oscillator.
   Frequency________cycles
3. Use the following parts in the multivibrator:
   Plate resistors, 10,000 ohms.
4. Measure the frequency of the resulting square waves.
   Frequency________cycles

Coupling Capacitors

1. Use the following parts in multivibrator:
   Plate resistors, 22,000 ohms.
   Coupling capacitors, .001 μf.
   Grid leaks, 1 megohm.
2. Measure the resultant output frequency.
   Frequency________cycles
3. Use the following parts in the multivibrator:
   Coupling capacitors, .0001 μf.
4. Measure the resultant output frequency.
   Frequency________cycles

Grid Leaks

1. Use the following parts in the multivibrator:
   Plate resistors, 22,000 ohms.
   Coupling capacitors, .001 μf.
   Grid leaks, 1 megohm.
2. Measure the resultant output frequency.
   Frequency________cycles

3. Use the following parts in the multivibrator:
   Grid leaks, 100,000 ohms.
4. Measure the resultant output frequency.
   Frequency________cycles

CONCLUSIONS

1. In the right-hand column of figure 2, write a concise explanation of what is happening in the circuit to produce the observed waveforms. For example: under the heading, "Waveform at Left-Hand Plate," opposite "0—90°," write, "Negative grid voltage cuts off the left-hand triode. Plate voltage rises to B plus value." Trace the development of each waveform in this way, from 0 to 360 degrees.

2. From your notes, supply the missing information in the following sentences:

a. Changing the plate load resistors of this multivibrator from 100,000 ohms to 10,000 ohms ________ (increased or decreased) the frequency of oscillation by____percent.

b. Changing the coupling capacitors from .001 to .0001 μf. (increased or decreased) the frequency by ____ percent.

c. Changing the grid leaks from 1 megohm to 100,000 ohms ________ (increased or decreased) the frequency by ____ percent.

3. Why does a change in the values of the plate resistors in a plate-coupled multivibrator exert a relatively *small* influence upon frequency?

The plate resistors are not a part of the discharge circuit of the coupling capacitors. Since the multivibrator frequency depends largely upon the discharge time constants, frequency is controlled primarily by the values of the coupling capacitors and grid leaks — not by the values of the plate resistors.

4. Study the waveforms and explanations in Figure 3 and be prepared to answer questions concerning them.

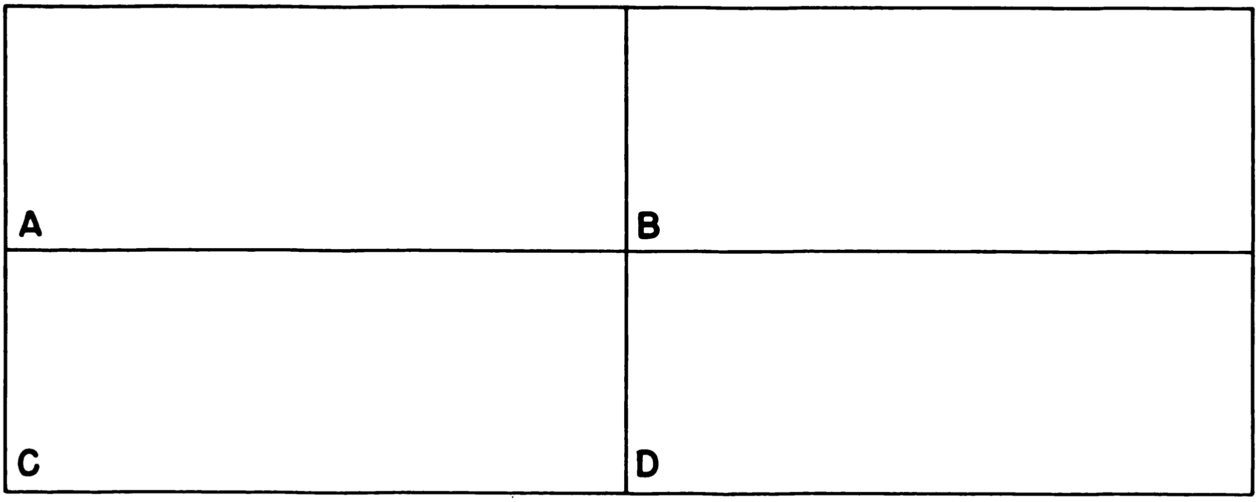
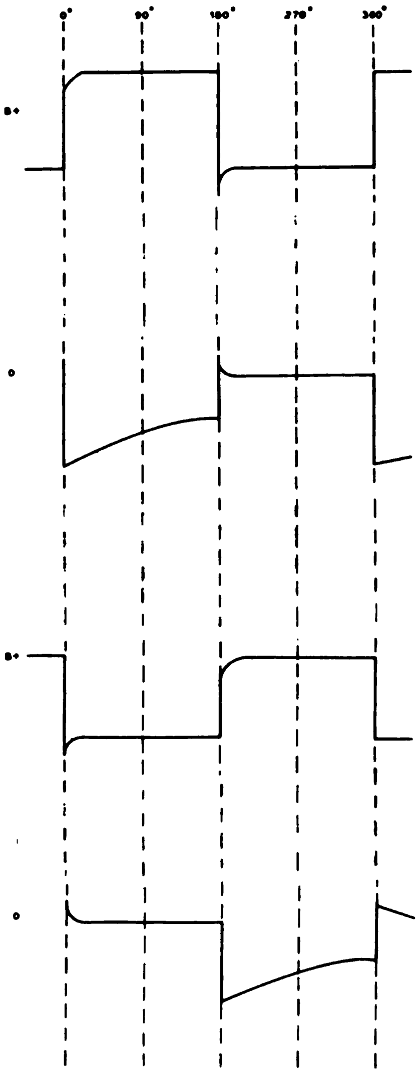
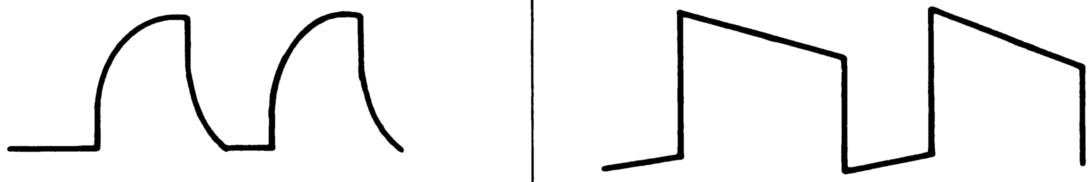


Figure 1. Waveforms Obtained from the Plate-Coupled Multivibrator



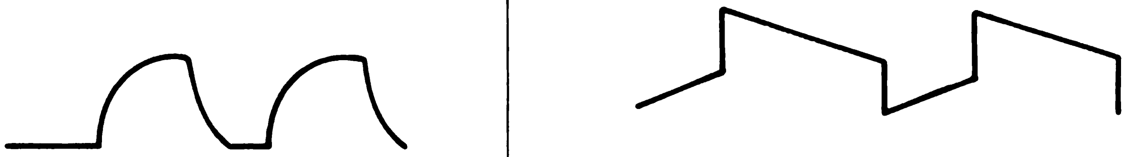
	Waveform at Left-Hand Plate
0— 90°	
90—180°	
180—270°	
270—360°	
Waveform at Left-Hand Grid	
0— 90°	
90—180°	
180—270°	
270—360°	
Waveform at Right-Hand Plate	
0— 90°	
90—180°	
180—270°	
270—360°	
Waveform at Right-Hand Grid	
0— 90°	
90—180°	
180—270°	
270—360°	

Figure 2. Synchrogram of The Waveforms in The Plate-Coupled Multivibrator. Explanation of Circuit Operation.



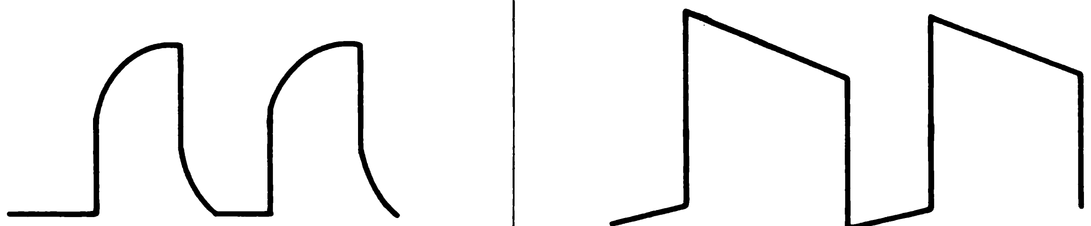
A. ROUNDED CORNERS CHARACTERISTIC OF HIGH-FREQUENCY SQUARE WAVE DISTORTION

B. SLANTING TOPS CHARACTERISTIC OF LOW-FREQUENCY SQUARE WAVE DISTORTION



. HIGH-FREQUENCY SQUARE WAVES, FURTHER DISTORTED BY A LOW-GAIN VERTICAL AMPLIFIER

D. LOW-FREQUENCY SQUARE WAVES, FURTHER DISTORTED BY A LOW-GAIN VERTICAL AMPLIFIER



. HIGH-FREQUENCY SQUARE WAVES, FURTHER DISTORTED BY A HIGH-GAIN VERTICAL AMPLIFIER

F. LOW-FREQUENCY SQUARE WAVES, FURTHER DISTORTED BY A HIGH-GAIN VERTICAL AMPLIFIER

Figure 3. Types of Waveform Distortion Occurring in Square Waves

LABORATORY PLAN No. 20

SUBJECT

The one-shot multivibrator.

OBJECTIVE

To supervise the testing of a one-shot multivibrator; to supervise the operational checks and the process of trouble-shooting the circuit.

MATERIAL REQUIRED

1. One-Shot Multivibrator Chassis.
2. Single-Swing Blocking Oscillator Chassis.
3. A-F oscillator with leads.
4. Five-inch oscilloscope, with cross-section screen and leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.

INTRODUCTION

The one-shot multivibrator circuit differs from the cathode-coupled multivibrator circuit in that the grid of the second triode section is returned to the cathode, instead of to ground.

SUBJECT MATERIAL

1. Show the class a One-Shot Multivibrator Chassis.

2. Supervise the testing of the circuit, and initial each student's workbook when he has completed the test.

3. Insist that the waveforms obtained in the section on the Effect of Circuit Constants Upon Waveform be neatly and accurately drawn.

4. Insert troubles into the students' equipment, and initial their workbooks.

5. Supervise the students' work in locating these troubles. As each student completes his work, verify his success in removing all the troubles inserted, and initial his workbook.

6. Insist that the JOB SHEET be properly filled out and submitted for grading.

CONCLUSIONS

The one-shot multivibrator is so designed that the pulse width is variable. Therefore, it is useful as a generator of gate pulses and as a variable time-delay circuit.

EXPERIMENT No. 20

SUBJECT

The one-shot multivibrator.

OBJECTIVE

To test and study the design of one-shot multivibrator; to become familiar with the idea of variable time-delay circuits and gating; to study the effect of circuit constants upon the generated waveform; and to obtain experience in trouble shooting this equipment.

MATERIAL REQUIRED

1. One-Shot Multivibrator Chassis.
2. Single-Swing Blocking Oscillator Chassis.
3. A-F oscillator with leads.
4. Five-inch oscilloscope, with cross-section screen and leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.

INSTRUCTIONS

The one-shot multivibrator circuit differs from the cathode-coupled multivibrator circuit in only one respect; the grid of the second triode section is returned to the cathode, instead of to ground. The special value of the one-shot multivibrator lies in its ability to generate pulses of adjustable width. It is used in radar equipment as a generator of gate pulses, and as a variable time-delay circuit.

PROCEDURE

Testing

1. Obtain the equipment listed under MATERIAL REQUIRED.
2. Put SS-2 in the normal position in the single-swing blocking oscillator.
3. Put SS-1 in normal position in the one-shot multivibrator.
4. Connect the one-shot multivibrator adjacent to the Single-Swing Blocking Oscillator Chassis.
5. Measure the peak amplitude of the trigger pulses being delivered by the blocking oscillator. This peak amplitude must be between 20 and 50 volts for satisfactory operation. If the trigger pulse does not fall within this range, consult the instructor.
6. When the proper trigger pulse has been obtained, connect the vertical lead of the scope to the OUTPUT jack J3 (plate of right-hand triode) of the one-shot multivibrator. A rectangular wave should be obtained.
7. Vary the multivibrator potentiometer over its entire range. The pulse width should vary from nearly zero to a point where it occupies more than half a cycle.
8. Transfer the vertical scope lead to the OUTPUT jack J4 (plate of left-hand triode) of the multivibrator. A similar waveform should be obtained.
9. Do not proceed with the EXPERIMENT until all these indications have been approved by the instructor.

Instructor's initials_______

Effect of Circuit Constants Upon Waveform

1. Refer to figure 1. Each square in this figure provides space for sketching the waveform obtained when *one* of the multivibrator circuit constants is changed from its normal value.
2. Make the indicated changes, and sketch the resultant waveforms in the appropriate squares.
3. In all cases, vary the potentiometer over its entire range. Sketch the widest obtainable pulse in solid lines; sketch the narrowest obtainable pulse in dotted lines.

Trouble Shooting

1. The instructor will insert troubles into the equipment.

Instructor's initials_______

2. Locate and remove these troubles, and return to the instructor any defective parts you discovered during the trouble-shooting procedure. Ask the instructor to verify your success in removing all troubles.

Instructor's initials______

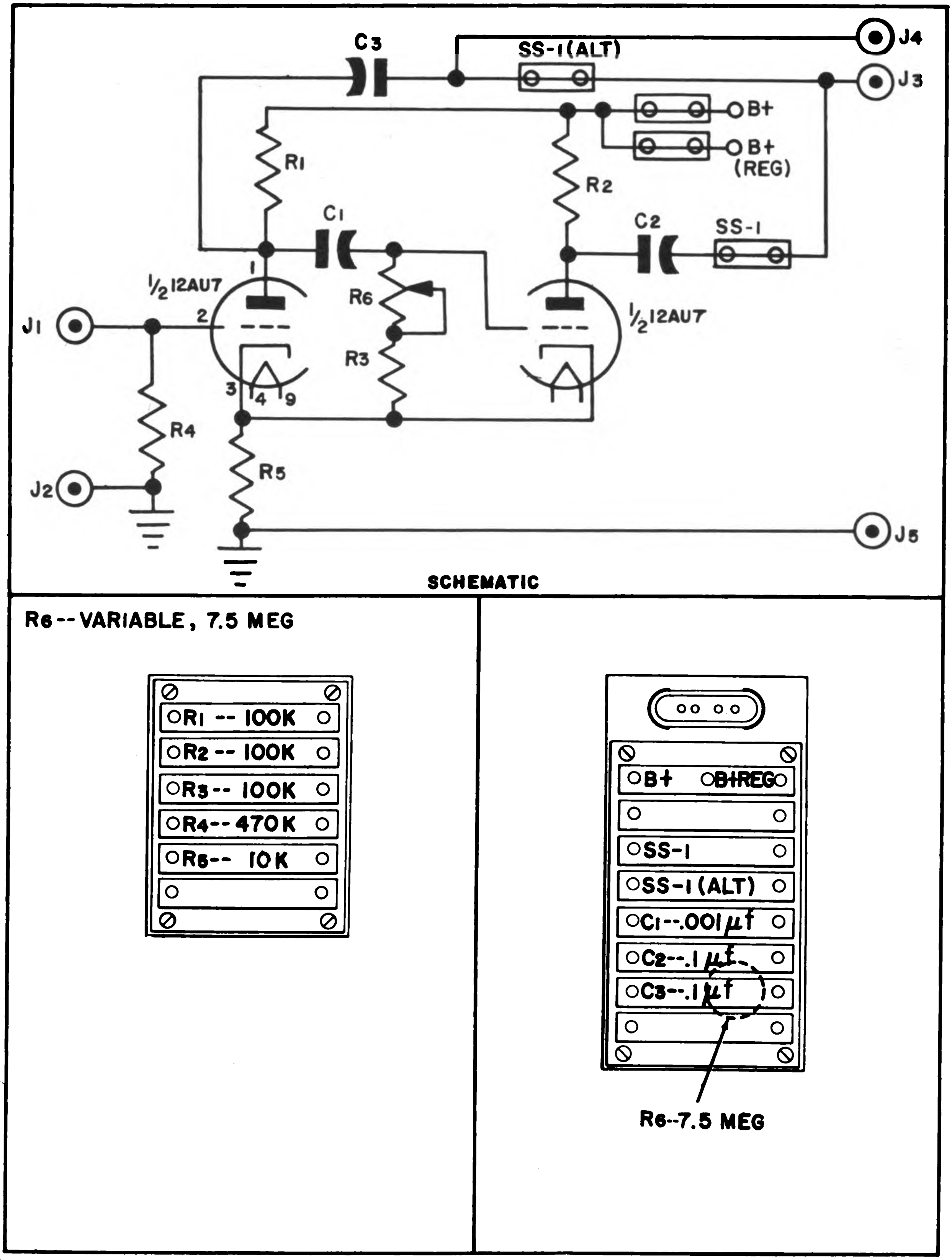
3. Fill out the attached JOB SHEET, and attach it to the EXPERIMENT for grading.

CONCLUSIONS

1. Using any reference books available, determine several ways of using a one-shot multivibrator in a radar chain. Draw block diagrams of the equipment used in each case, showing input and output waveforms. Give the book, author, and page number from which your information was drawn.
2. From the results recorded in figure 1, make a general statement regarding the effects upon waveform of the important circuit constants of the one-shot multivibrator. Analyze, combine, and simplify this information as much as possible.

ALL CONSTANTS AS SHOWN IN SCHEMATICS	ALL CONSTANTS AS SHOWN IN SCHEMATICS	ALL CONSTANTS AS SHOWN IN SCHEMATICS	ALL CONSTANTS AS SHOWN IN SCHEMATICS	ALL CONSTANTS AS SHOWN IN SCHEMATICS
$R_1 = 470K$	$C_3 = .01\mu F$	1K CATHODE RESISTOR IN TRIGGER GEN.	$R_5 = 39K$	$R_4 = 39K$
$R_2 = 470K$	$C_3 = .0001\mu F$	270.0 OHM CATHODE RESISTOR IN TRIGGER GEN.	$R_5 = 1K$	$R_4 = 2.2$ MEG.

Figure 1. Effect of Circuit Constants Upon One-Shot Multivibrator Waveforms



Schematic Diagram of One-Shot Multivibrator Chassis

JOB SHEET

Student's Name______________________________________

Section____

INDICATION (no output, distortion, hum, pickup, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)

LABORATORY PLAN No. 21

SUBJECT

The phantastron circuit.

OBJECTIVE

To demonstrate to the class the operation of the phantastron circuit and some of its uses.

MATERIAL REQUIRED

1. Phantastron Demonstration Unit.
2. Single-Swing Blocking Oscillator Demonstration Unit.
3. Power Supply Demonstration Unit.
4. Vacuum-tube voltmeter with leads.
5. Five-inch oscilloscope with leads.

INTRODUCTION

This EXPERIMENT will be in the form of a laboratory demonstration. Each student is to record the voltage measured and synchrograms developed during the demonstration. It will be the responsibility of the student to have a complete set of notes on the diagrams, analyses, and explanations given during the laboratory session.

The applications of this circuit are given in the EXPERIMENT.

SUBJECT MATERIAL

1. Draw a diagram of the phantastron circuit on the blackboard. Refer to the diagram given in the PROCEDURE section of the EXPERIMENT.

2. Give a preliminary explanation of the tube elements, and their function in the circuit. Refer to the EXPERIMENT for the details necessary for this explanation.

3. Copy from the EXPERIMENT an equivalent circuit of the phantastron, including all labels. Allow enough time for the students to copy the diagram in their notebooks.

4. Give a preliminary explanation of the circuit operation. Refer to the EXPERIMENT on the phantastron.

5. Call upon a student to make the d-c voltage measurements, as indicated in the table attached to the EXPERIMENT. This is to be done with the trigger removed.

6. Have the students record the values as the measurements are being made.

7. Call upon another student to repeat the d-c voltage measurements when a positive pulse with a repetition frequency of 160 cycles is used as a trigger.

8. Explain why grid No. 3 swings above cutoff, even though the voltage across resistor R6 remains constant. Refer to the appropriate section in the EXPERIMENT.

9. Apply a recurrent positive trigger pulse to the phantastron circuit, and display the cathode waveform on the scope. Measure the frequency of the phantastron input and output on the scope.

10. Vary the input frequency, and show that the output frequency will vary accordingly.

11. Remove the coupling capacitor, C1. Explain why oscillations cease. (Refer to the EXPERIMENT.)

12. Turn off the trigger, replace capacitor C1, and replace resistor R6 with a 10,000-ohm resistor. Measure the voltage between ground and the cathode, ground and grid No. 1, and ground and grid No. 3.

13. Explain briefly how oscillations occur. Refer to the appropriate section of the EXPERIMENT.

14. Display on the oscilloscope the waveforms developed in the phantastron circuit when the input trigger is adjusted to 160 cycles, with resistor R2 in the circuit adjusted to produce a cathode waveform whose flat-top portion is 4000 microseconds long. Allow enough time between each exhibit to permit the students to copy these waveforms, to produce a synchrogram.

15. Display the output waveform obtained when the circuit is triggered at the rate of 160 cycles. Then vary potentiometer R2, and point out the variation of the output pulse width. Explain that this occurs because the RC time constant of the discharge path of capacitor C1 is changed.

CONCLUSIONS

Summarize briefly the important aspects of this demonstration.

The advantage of the phantastron over similar types of circuits is that the output pulse duration may be made very nearly a linear function of changes in the control voltage.

As brought out by the EXPERIMENT, the phantastron circuit may be triggered by either a positive or negative recurrent pulse.

EXPERIMENT No. 21

SUBJECT

The phantastron circuit.

OBJECTIVE

To become familiar with the operation of the phantastron circuit, and some of its uses.

REFERENCES

Lecture notes taken during class.

INSTRUCTIONS

This EXPERIMENT will be in the form of a laboratory demonstration, performed by the instructor. The voltage measurements and synchrograms developed during this demonstration are to be recorded in the table attached to this EXPERIMENT. It will be the responsibility of the student to have a complete set of notes on the diagrams, analyses, and explanations given by the instructor during this demonstration.

The phantastron circuit is widely used as a means of switching radar chains on and off, and providing a controllable delay time, independent of the trigger pulse.

It will be shown that this circuit, employing a pentagrid type tube, is similar to that of the cathode-coupled multivibrator using a dual triode.

A study will be made of the d-c voltage conditions existing in the circuit when the plate is at cutoff; when the condition is reversed, with the plate drawing current; and when the circuit is being triggered by a recurrent trigger pulse.

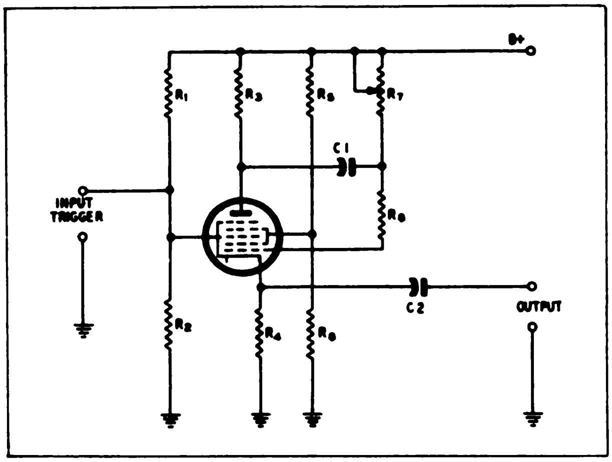
PROCEDURE

Circuit Diagram

1. Copy the diagram of the phantastron circuit which the instructor will draw on the blackboard. Include all labels and values.

2. Make a set of notes on the instructor's preliminary explanation of the tube elements and their functions in the circuit.

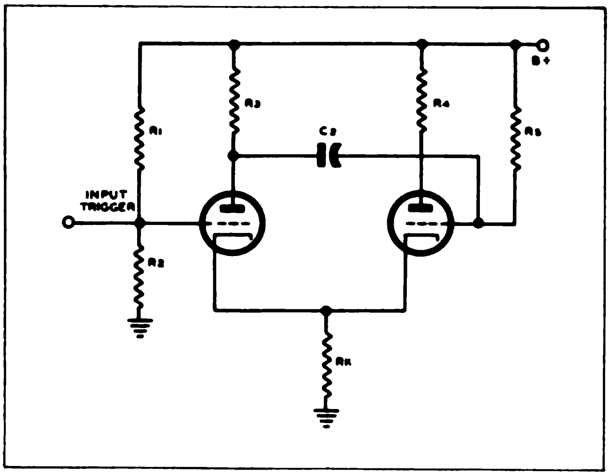
The 6BE6 pentagrid tube is similar to a pentode except that the screen grid of the pentode is replaced by a structure comprising grids No. 2 and 4. Grid No. 1 is a normal control grid determining the total cathode current. Grids No. 2 and 4 operate as a screen. The second control grid, No. 3, controls the division of current between the screen and the plate. Grid No. 5 is a conventional suppressor.



Schematic Diagram of Phantastron

Equivalent Circuit Diagram

1. Copy the equivalent circuit diagram of the phantastron circuit which the instructor will draw on the blackboard. Include all labels.



Equivalent Circuit of Phantastron

2. Make a set of notes on the instructor's preliminary explanation of the circuit operation.

1. Positive trigger pulse is applied to No. 3.

2. Plate current (I_p) starts to flow, causing plate voltage (E_p) to decrease sharply.

3. The change in plate voltage is coupled to grid No. 1 through capacitor C1 driving the grid negative.

4. The negative grid No. 1 reduces the current flow through the whole tube, reducing the voltage drop across R7. (When G3 is driven positive and I_p starts to flow, the increase in I_p is not as great as the decrease in I_s. Consequently, the total cathode current decreases.)

5. Less positive voltage on the cathode makes gride No. 3-to-cathode voltage more positive, increasing I_p.

6. Since grid No. 3 controls the division of current between plate and screen (grids No. 2 and No. 4), the increase in I_p is accompanied by a decrease in screen current.

7. After the initial sharp increase in I_p, and decrease in I_{sg}, both I_p and I_{sg} increase slowly.

8. At the same time when I_p is increasing and E_p is decreasing, C1 is discharging through R5, causing the voltage at grid No. 1 to rise slowly.

9. The increasing current through the tube causes an increasing voltage drop across R_k, which eventually reaches a point where the grid No. 3-to-cathode voltage reaches I_p cutoff.

10. Plate current ceases to flow, and screen current goes quickly to maximum. The plate voltage rises to the B+ value exponentially as C1 takes on its charge through R3.

11. The circuit returns to the static condition.

D-C Voltage Measurements

1. In the attached table for voltage measurements, record the values of d-c voltage measured at various points throughout the circuit, with the trigger removed.

2. Record in the table the values of d-c voltage measured at the same points in the circuit when a positive pulse with a recurrence rate of 160 cycles, from the single-swing blocking oscillator, is used as a trigger.

3. On the equivalent circuit drawing, copied earlier in this demonstration, enter the data recorded in the table.

4. In view of these measured voltages, why does grid No. 3 swing above cutoff, even though the voltage across resistor R6 remains constant?

The pulse of plate current drives the grid potential down, decreasing the cathode current. This, in turn, decreases the cathode potential, and I_p comes out of cutoff.

Triggered Operation

1. The instructor will now apply a recurrent positive trigger pulse to the phantastron circuit, and display the cathode waveform on the scope. He will then measure the frequency of the phantastron, and show the relationship of the input and output frequencies. Record your observations.

The frequency of output is the same as the frequency of input.

2. The instructor will vary the input frequency. In the space below, record your observations concerning the output frequency.

An increase in input frequency produces a corresponding increase in the output frequency. A decrease in input frequency produces a corresponding decrease in output frequency.

3. The instructor will remove the coupling capacitor, C1. It will be observed that oscillation will cease. In the space below, record the instructor's explanation.

When the coupling capacitor is removed, changes in plate voltage cannot be coupled to grid No. 1; because there is no feedback, therefore, there is no reduction of current flow through the tube, and oscillations cease.

Waveforms

1. The instructor will display on an oscilloscope the waveforms developed in the phantastron circuit when the input trigger is adjusted to 160 cycles. In the space on page 247, construct a synchrogram of these waveforms, being careful to show them in proper phase relationship with each other.

2. The instructor will display the cathode output of the phantastron when the circuit is triggered at the rate of 160 cycles. He will then vary potentiometer R2. Observe the variation in the width of the pulse. Record the instructor's explanation of this variation.

Varying R2, changes the RC time constant of the discharge path of C1. This changes the time required for the capacitor to discharge, thus changing the duration of the pulse.

CONCLUSIONS

Summarize the facts brought out by this demonstration, with emphasis on the following; the function of the various tube elements; why the circuit oscillates with a positive trigger applied to grid No. 3; the variations in pulse width; the use of a positive or negative trigger; the applications of the phantastron circuit.

The operation of the phantastron depends on the characteristics of the pentagrid tube. Grid No. 1 controls cathode current; grid No. 3 controls the distribution of current between the

Synchrogram of Waveforms Developed in the Phantastron Circuit

screen grids, No. 2 and No. 4, and the plate. Grid No. 5 is an ordinary suppressor grid. If a positive trigger is applied to grid No. 3, current flows to the plate. This action supplies a negative pulse to grid No. 1, decreasing the total current, but increasing the plate current in a regenerative action. After the pulse, capacitor C1 discharges, raising the potential at grid No. 1, increasing the plate current still more. When the voltage on grid No. 1 reaches the value where a further increase will decrease the plate current, the tube switches back to the condition of equilibrium. The pulse width may be varied by changing the value of resistance in the discharge path of the coupling capacitor. The circuit may be triggered by a negative pulse, as well as by a positive pulse, by applying the trigger to grid No. 1. In radar, the phantastron is often triggered by the transmitter and used to produce a spike occurring at some adjustable time interval.

TABLE OF VOLTAGES AND CURRENTS IN THE PHANTASTRON CIRCUIT, UNDER TRIGGERED AND UNTRIGGERED CONDITIONS

VOLTAGE DROP ACROSS	FUNCTION OF RESISTOR	RESISTANCE VALUE (ohms)	CIRCUIT TRIGGERED		CIRCUIT UNTRIGGERED	
			VOLTAGE (volts)	CALCULATED CURRENT (ma.)	VOLTAGE (volts)	CALCULATED CURRENT (ma.)
R1		1 meg				
R6		100 K				
R3		470 K				
R7		10 K				
R4		33 K				
R8		100 K				
R2		7 meg pot				
R5		470 K				

LABORATORY PLAN No. 22

SUBJECT

The self-pulsing blocking oscillator.

OBJECTIVE

To supervise the testing and operational checking of the self-pulsing blocking-oscillator circuit.

MATERIAL REQUIRED

1. Self-Pulsing Blocking Oscillator Chassis.
2. Triode Limiter Chassis.
3. A-F oscillator with leads.
4. Five-inch oscilloscope, with leads and cross-section screen.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.

INTRODUCTION

This type of oscillator is characterized by its ability to generate several complete sine-wave cycles of very-high or ultra-high frequency for a short duration, and then cease to oscillate for a relatively long interval. This action may be termed a cycle of operation.

SUBJECT MATERIAL

1. Exhibit a Self-Pulsing Blocking Oscillator Chassis to the class to familiarize them with the various components.

2. Set up a properly functioning Self-Pulsing Blocking Oscillator Chassis, and display on an oscilloscope the correct output waveforms. Keep the equipment hooked up, so that the students can compare their observed output waveforms with the correct form, during the testing of the circuit.

3. Conduct a brief demonstration of the section in the EXPERIMENT concerning the Factors Affecting Frequency of Oscillation. Refer to the steps given in the EXPERIMENT.

4. Give a demonstration covering the section concerning the Factors Affecting Pulse Repetition Frequency.

5. Give a demonstration covering the section concerning Synchronization. As you proceed, explain to the class what is occurring in the circuit.

CONCLUSIONS

The self-pulsing blocking oscillator is used in the ultra-high frequency stage of some radars, such as in IFF and similar equipment. It is important to keep in mind the distinction between the fundamental radio frequency, determined by the LC constant of the tank circuit, and the pulsing frequency, which is determined by the RC time constant of the grid circuit.

EXPERIMENT No. 22

SUBJECT

The self-pulsing blocking oscillator.

OBJECTIVE

To become familiar with the operation of this type of oscillator, both in the blocked and unblocked conditions; to investigate the effects of various circuit constants upon pulse width; and to study methods of synchronizing the oscillator, in order to make it produce a predetermined pulse repetition frequency.

MATERIAL REQUIRED

1. Self-Pulsing Blocking Oscillator Chassis.
2. Triode Limiter Chassis.
3. A-F oscillator with leads.
4. Five-inch oscilloscope, with cross-section screen and leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.

INSTRUCTIONS

The self-pulsing blocking oscillator differs from the single-swing types previously studied in that, in one pulsing period, it delivers several cycles of output voltage, instead of a single cycle. One application of the self-pulsing blocking oscillator is in the u-h-f oscillator stage of some radar, IFF and similar equipments. Its purpose is to excite the transmitting antenna of the equipment for a few microseconds (or even less) with u-h-f oscillations. This pulse of energy is radiated in a straight line, strikes the target, and is reflected back to the antenna, where it is used to excite the radar receiver. The transmitted oscillatory power must be sent out in very narrow pulses, so that signals returning to the receiver will not be masked by power being generated by the transmitter at the instant when the echoes return from the target.

A typical equipment, when adjusted for short-range work, might transmit at a frequency of 500 megacycles for one-half microsecond. The transmitter then would cease to operate for a period sufficiently long for the most distant echoes to return. The transmitted energy might travel outward for a distance of five miles, strike a target, be reflected, and return over the five-mile path to the receiver, where it would be recorded as a bright spot on the radar indicator. Such a trip — five miles out, five miles back — would require about 62 microseconds of time. If, during that period, the transmitter were to produce another pulse, the receiver would be paralyzed, and would be unable to record an incoming reflection from a target. Therefore, the transmitter, after emitting its half-microsecond burst of radiated energy, remains inactive for 124 microseconds. This allows time for all echoes from targets within a range of 10 miles to return to the receiver. At the end of this 124-microsecond interval, the transmitter produces another half-microsecond burst of radiated energy, and then cuts off for another 124 microseconds, awaiting the return of any echoes from targets within a 10-mile range.

The duration of the transmitted pulse is called the "pulse width." The pulse consists of a large number of individual cycles of radiated energy which occur at an ultra-high frequency (in this case, 500 megacycles per second). The number of

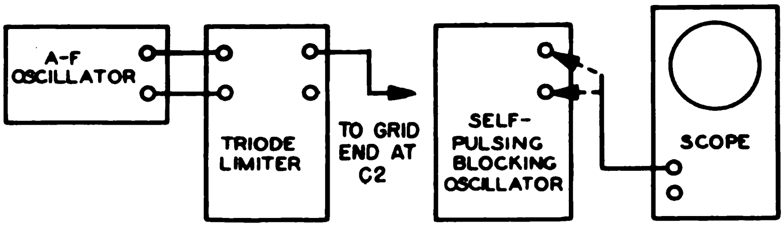


Figure 1. Block Diagram of Equipment Setup for the Self-Pulsing Blocking Oscillator Experiment

half-microsecond pulses emitted during a second is called the "pulse repetition frequency" (in this case, it is 1,000,000/124 = 8065 pulses per second).

The laboratory equipment to be used in this EXPERIMENT operates at much lower frequencies and pulse repetition frequencies than standard equipments, and its pulses are much wider. This is necessary to permit measurements of the circuit characteristics on the 5-inch oscilloscopes available for student use. The theory of operation, however, is the same in both cases.

In this EXPERIMENT, the student will investigate the effect of the grid capacitor and grid leak upon pulse width and pulse repetition frequency; he will measure the frequency of the individual sine waves that make up the pulses; and he will study methods of synchronizing the self-pulsing blocking oscillator by means of a stable audio-frequency oscillator.

PROCEDURE

Testing

1. Connect the vertical lead of the scope to the OUTPUT jack J1 of the blocking-oscillator chassis (the oscillator plate). Turn the blocking-oscillator potentiometer to near its minimum-resistance position. A rectangle of light now appears on the scope screen, indicating that the oscillator is producing unblocked sine waves at a high audio frequency.

2. Turn the coarse frequency control knob of the scope to its highest-frequency range, and adjust the fine frequency control knob until a line of sinusoidal waveforms appears on the screen.

The line observed is the waveform produced by the oscillator when the grid-leak potentiometer is adjusted to such a low value that periodic blocking does not occur.

3. Turn the potentiometer slowly toward the high-resistance position. At some point, the sine-wave trace will dissolve into a maze of lines, indicating that the oscillator has started to block. It is now producing short bursts of oscillation, separated by long periods during which no oscillation occurs.

4. Turn the coarse frequency control knob of the scope back to one of its lower settings, and adjust the fine frequency control knob until you obtain three pulses of oscillation, separated by a bright line along the center of the screen.

This display proves the statement made in step 3 — that the oscillator is producing narrow pulses of oscillation, separated by "resting periods," during which no oscillation occurs.

5. Transfer the vertical scope lead to the grid end of C2 (the blocking-oscillator grid). Make minor adjustments to the scope until it displays three wave trains, separated by bright lines that rise exponentially between pulses. Record this waveform at D in figure 2.

This display represents the voltage on the grid, which is driven highly negative during each wave train, and then relaxes over an exponential path until the voltage reaches the cutoff value. As soon as it passes this point, plate current starts to flow, and another short period of oscillation occurs.

6. If any of the indications described in the preceding steps are not observed, find and correct the trouble. If necessary, ask an instructor for help.

Factors Affecting Frequency of Oscillation

Tank Capacitor C1

1. Transfer the oscilloscope lead to the output of the blocking oscillator.

2. Adjust the blocking-oscillator potentiometer until a series of sine waves appears on the scope screen.

3. Measure the frequency of these oscillations by comparison with the output of an a-f oscillator.

Frequency________cycles

Note that these oscillations are being produced by the action of the circuit while functioning as a conventional Hartley oscillator, without blocking. The frequency of oscillation depends upon the inductance and the shunt capacitance in the tank circuit.

4. Remove the .0001-μf. capacitor, C1, from the tank circuit, and replace it with a .001-μf. capacitor.

5. Observe that the frequency of the oscillator has decreased. Measure and record this new frequency.

Frequency______cycles

6. Does this new frequency agree with what you would have calculated it to be, using the formula: $f = \frac{1}{2\pi}\frac{1}{\sqrt{LC}}$? If there is a discrepancy, indicate the possible causes.

The discrepancy may be due to error in reading the oscilloscope and in comparing the frequencies of the oscillator and signal generator. It may also be due to the tolerance ratings of the inductors and capacitor.

Tank Inductors L1 and L2

1. Insert the .0001-μf. capacitor at C1 again.

2. Measure the frequency of the oscillations produced by the circuit. This should check with the measurement made in step 3 under Tank Capacitor C1.

Frequency_______cycles

3. Remove the 10-mh. inductors, L1 and L2, and replace them with 2.5-mh. inductors.

4. Measure and record the resultant output frequency.

Frequency ______ cycles

5. Calculate the frequency at which these two coils, in series, should resonate when tuned by a .0001-μf. capacitor at C1. Explain any discrepancy between your calculations and the observed output frequency.

If discrepancies had occurred they might have been caused by reading errors of tolerance.

6. Remove the 2.5-mh. inductors from the tank circuit, and replace the 10-mh. inductors normally used in the circuit at L1 and L2.

Effect of Grid Capacitor C2 Upon Pulse Width

1. Vary the blocking-oscillator potentiometer until a pulse repetition frequency of 400 p.p.s. is obtained.

2. Measure the width of the wave train, using the method described in the INFORMATION SHEET on time measurements with a linear sweep.

Width _____ microseconds (C2 = .001 μf.)

3. Replace the .001-μf. grid capacitor C2 with a .01-μf. capacitor. Again set the repetition frequency at 400 p.p.s., and measure the width of the wave train.

Width _____ microseconds (C2 = .01 μf.)

4. What conclusion do you draw as to the effect of grid capacitance upon the width of the wave train produced?

Factors Affecting Pulse Repetition Frequency

1. Reinsert the .001 μf. capacitor at C2.

2. Rotate the grid-leak potentiometer from the point where blocking barely starts to the point where the lowest obtainable pulse repetition frequency occurs. Measure and record the range of pulse repetition frequencies produced. Note whether the potentiometer has a high or a low resistance at the high-frequency setting.

Highest pulse repetition frequency, _____ p.p.s.
Resistance _____ (high or low)
Lowest pulse repetition frequency, _____ p.p.s.
Resistance _____

3. Remove the .001-μf. capacitor from C2, and replace it with a .01-μf. capacitor. Measure and record the range over which the pulse repetition frequency can be varied by rotating the potentiometer. Note whether the potentiometer has a high or a low resistance at the high-frequency setting.

Highest pulse repetition frequency, _____ p.p.s.
Resistance _____ (high or low)
Lowest pulse repetition frequency, _____ p.p.s.
Resistance _____

4. What conclusions do you draw regarding the relationship between grid capacitance and pulse repetition frequency? Between grid-leak resistance and pulse repetition frequency?

Increasing either the grid capacitance or the grid-leak resistance decreases repetition frequency.

Synchronization

1. Connect the equipment as shown in the block diagram, figure 1. Insert a shorting strip in place of the resistor at R2 in the triode limiter. This converts the limiter for use as a conventional voltage amplifier.

2. Apply the synchronizing voltage from the output of the triode-limiter amplifier to the grid end of C2 of the blocking oscillator.

3. Adjust the pulse repetition frequency of the blocking oscillator to 400 pulses per second. Adjust the a-f oscillator to a frequency of 400 cycles per second. Adjust the scope to present three cycles of the waveform occurring at the OUTPUT jack (plate) of the blocking oscillator.

4. At E in figure 2, record the plate waveform appearing on the scope screen.

5. Connect the oscilloscope to the output of the triode limiter. Make minor adjustments to the scope until it displays three sine waves, with each positive peak triggering off a pulse of high audio-frequency oscillations. Apply just enough synchronizing voltage to produce this effect. Record the resultant waveform at A in figure 2.

6. Slowly increase the frequency of the a-f oscillator to 800 cycles. If necessary, adjust the scope sync voltage, to hold the trace steady. At B in figure 2, record the resultant waveform.

7. Advance the a-f oscillator frequency to 1200 cycles; at C in figure 2, record the waveform observed.

8. Increase the amplitude of the a-f oscillator voltage slowly, noting the changes in the appearance of the trace. Explain why these changes occur.

Varying the synchronizing voltage results in a distorted output. The sweep was pulsed too often, and irregularly.

CONCLUSIONS

1. To what use can the self-pulsing blocking oscillator be put?

It can be used for transmitting for a short time and resting for a longer period.

2. What is meant by the "pulse width" of the self-pulsing blocking-oscillator output?

The pulse width of the self-pulsing blocking oscillator is the length of time during which oscillations occur.

3. What is meant by pulse repetition frequency?

The pulse repetition frequency is the rate of recurrence of pulses.

4. What circuit constants control pulse (wave train) width?

a. The capacitance at C2.
b. B+ (plate supply) voltage.
c. The cutoff voltage of the tube.

5. What circuit constants control repetition frequency?

a. The capacitance at C2.
b. The resistance of the grid leak.
c. The cutoff voltage of the tube.

6. What circuit constants control the frequency of the sine waves produced?

a. The inductance at L1 and L2.
b. The capacitance at C1.

7. Explain in detail the formation of the synchronized grid voltage trace of B in figure 2.

The trace shows the sine-wave input from the triode amplifier. On every second cycle, the synchronizing voltage becomes large enough to drive the tube from cutoff and into oscillation.

A
GRID WAVEFORM, FUNDAMENTAL SYNC.

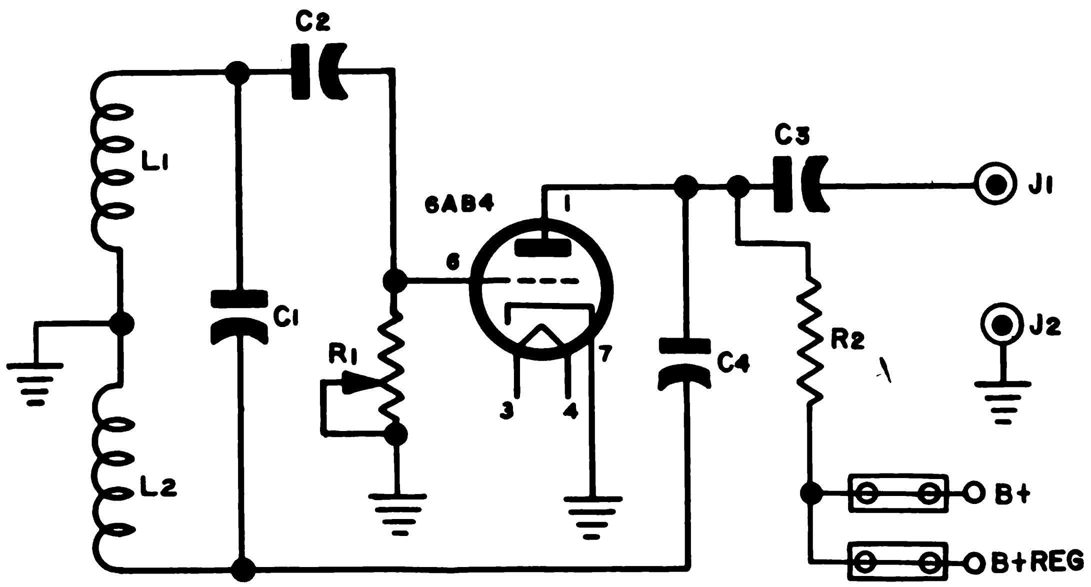
B
GRID WAVEFORM, 2ND HARMONIC SYNC.

C
GRID WAVEFORM, 3RD HARMONIC SYNC.

D
GRID WAVEFORM
(UNSYNCHRONIZED)

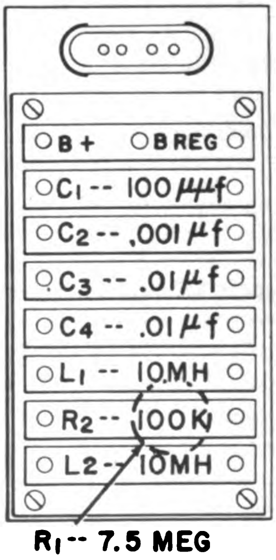
E
PLATE WAVEFORM
(UNSYNCHRONIZED)

Figure 2. Waveforms Obtained from a Self-Pulsing Blocking Oscillator



SCHEMATIC

R1 -- VARIABLE, 7.5 MEG.



Schematic Diagram of Self-Pulsing Blocking Oscillator Chassis

LABORATORY PLAN No. 23

SUBJECT

The shock-excited peaking oscillator.

OBJECTIVE

To supervise the testing and adjusting of the shock-excited peaking oscillator.

MATERIAL REQUIRED

1. Shock-Excited Peaking Oscillator Chassis.
2. Square Wave Generator Chassis.
3. Parallel Diode Limiter Chassis.
4. Bias Supply Chassis.
5. Five-inch oscilloscope with cross-section screen and leads.
6. Vacuum-tube voltmeter with leads.
7. A-F oscillator with leads.
8. Additional plug-in parts as follows:
   Resistor, 100,000 ohms.
9. Power Supply Chassis.

INTRODUCTION

In radar equipment, it is often desirable to produce trigger pulses that are extremely narrow and of a predetermined pulse repetition frequency. One easy method of accomplishing this is by means of a shock-excited peaking oscillator.

SUBJECT MATERIAL

1. Continue the program of supervision, as was done in previous EXPERIMENTS. Approve the students' work before permitting them to continue.

2. Conduct a brief demonstration indicating the results to be expected of the students in the Adjustment and Familiarization and the Measurement of Waveforms sections of the EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there.

3. Insist that the students draw neat and accurate waveforms.

CONCLUSIONS

As will be shown in this EXPERIMENT, a vacuum tube may be used as a switch to interrupt the steady flow of plate current through a resonant L-C tank circuit, as a means of setting up oscillations in the tank. Such a circuit is known as a shock-excited oscillator, and finds practical applications in instances where oscillations of a certain frequency occurring over short intervals of time are required periodically. If the Q of the tank circuit is made low, by increasing the series resistance associated with the coil, the oscillator circuit may be used to produce very sharp, narrow peaks at a rate controlled by the voltage applied to the grid of the tube. The chassis used during this EXPERIMENT will be used later in the course as a means of producing narrow radar marker pips.

EXPERIMENT No. 23

SUBJECT

The shock-excited peaking oscillator.

OBJECTIVE

To show that a tank circuit can be shocked into oscillation, producing a train of damped waves; to show that this wave train, by further damping, can be converted into a series of sharp positive pulses.

MATERIAL REQUIRED

1. Shock-Excited Peaking Oscillator Chassis.
2. Square Wave Generator Chassis.
3. Parallel Diode Limiter Chassis.
4. Bias Supply Chassis.
5. Five-inch oscilloscope with cross-section screen and leads.
6. Vacuum-tube voltmeter with leads.
7. A-F oscillator with leads.
8. Additional plug-in parts as follows:
   Resistor, 100,000 ohms.
9. Power Supply Chassis.

INSTRUCTIONS

In radar equipment, it is often desirable to produce trigger pulses that are extremely narrow, and of a predetermined pulse repetition frequency. One easy method of accomplishing this is by means of a shock-excited peaking oscillator.

The shock-excited peaker to be studied in this EXPERIMENT uses a 150 mh. tank coil, tuned by a .01-μf. capacitor. When shocked into oscillation, this tank circuit produces a damped wave train whose individual cycles are less than 300 microseconds wide. A variable resistor in series with this circuit provides variable damping, and makes it possible to suppress all but a fraction of the first half-cycle. The positive pulse that remains is very sharp — on the order of 60 microseconds wide, or even less. Its pulse repetition frequency is rigidly controlled by a square-wave generator, which furnishes the negative-going square wave that shocks the peaker into oscillation. Any negative-going peaks that may form as a by-product of the gating pulse can be removed by a parallel diode limiter.

PROCEDURE

Adjustment and Familiarization

1. Set up the equipment as shown in the block diagram, figure 1. Do not, as yet, connect the Bias Supply Chassis.

2. In the square-wave generator insert 100,000-ohm resistors for the grid leaks R5 and R6. Connect the scope lead to the OUTPUT jack of the square-wave generator, and check for symmetrical square waves.

3. Connect the scope lead to the OUTPUT jack of the shock-excited peaking oscillator. Turn the knob of the damping resistor, R2, fully clockwise. This reduces damping to a minimum. Adjust the scope to present two damped wave trains. Study the individual cycles. Note that the first pulse is positive; that successive cycles decay exponentially.

4. Slowly turn the knob of the damping resistor, R2, in a counter clockwise direction. Note that the amplitude of the individual cycles decreases. The right-hand cycles merge into the base line, one by one, until only the first alternation remains. Note, also, that there is a broad negative pulse at the point where the negative gate from the square-wave generator ends. Vary the R2 knob back and forth several times, until you have become thoroughly familiar with this sequence of changes.

5. In the parallel diode limiter, insert a shorting strip in the ALT. 3 position. This converts the limiter so that it will remove most of the negative pulse observed in step 4, above. Turn the damping resistor knob of the shock-excited oscillator fully counterclockwise, so as to produce a sharp positive spike and a broad negative pulse.

6. Connect the scope lead to the OUTPUT jack of the parallel diode limiter. Transfer the scope lead back and forth between the limiter OUTPUT and INPUT jacks until you have become familiar with the appearance of the waveform before and after limiting.

7. Remove the shorting strip from the ALT. 3 position and insert it in the ALT. 4 position. Place the bias supply shorting strip in the regular position. This places a variable positive bias on the plate of the right-hand diode. Connect the scope to the OUTPUT jack of the limiter, and turn the positive bias-supply knob clockwise, so as to increase the positive bias on the plate. Observe that the low-amplitude negative pulse which remains when the diode is limiting at zero is still further reduced by application of this positive bias. Make whatever scope adjustments are necessary to maintain a stationary pattern.

Vary the bias back and forth, and study the changes that occur.

8. Demonstrate to the instructor the various waveforms obtained with this chain, and obtain his approval before proceeding.

Instructor's initials________

Measurement of Waveform

Width and Amplitude of Gate

1. Connect the scope lead to the OUTPUT jack of the square-wave generator.
2. Adjust the scope controls to present 4 cycles of the square-wave output voltage.
3. At A in figure 2, sketch the middle two cycles accurately. Start the negative-going edges of these two cycles at the two dotted lines provided in the figure.
4. Measure the width in microseconds of the two halves of the square wave, and enter these figures on the sketch.
5. Measure the peak-to-peak amplitude of the square waves, and enter this figure on the sketch.

Width and Amplitude of Damped Waves

1. Connect the scope lead to the OUTPUT jack of the shock-excited peaking oscillator.
2. After placing SS-1 of the bias supply chassis in its alternate position turn the damping resistor, R2, fully clockwise.
3. Adjust the scope to present 2 damped wave trains.
4. At B in figure 2, sketch two successive wave trains. Start the first positive pulse of each train directly beneath the negative-going edge of the gate pulse that produced the train.
5. Measure the width in microseconds of one of the cycles in the damped wave train, and enter this figure on the sketch.
6. Measure the width in microseconds of the entire damped wave train, and enter this figure on the sketch.
7. Measure the peak amplitude of the first positive alternation of the damped wave train, and enter the figure on the sketch.

Width and Amplitude of Pulses with Maximum Damping

1. Turn the damping resistor, R2, fully counterclockwise.
2. At C in figure 2, sketch the middle two cycles of the waveform obtained at the OUTPUT jack of the shock-exicted peaking oscillator. Place the positive pulse under the negative-going edge of the gate; place the leading edge of the broad negative pulse beneath the positive-going edge of the gate.
3. Measure the width in microseconds at the base of the positive pulse. Enter this figure on the sketch.

Width and Amplitude of Pulses with Maximum Damping and Negative Limiting

1. With the equipment adjusted as described above, turn the negative-bias control knob until the base line becomes as straight as possible.
2. At D in figure 2, sketch the two middle cycles of the waveform obtained.
3. Measure the width in microseconds at the base of the positive pulse, and enter this figure on the sketch.
4. Measure the peak amplitude of the positive pulses, and enter this figure on the sketch.

CONCLUSIONS

1. Explain, in your own words, how the shock-excited oscillator produces a train of damped waves when its grid is blocked by a negative gate pulse.

In the absence of a negative gate pulse, the tube conducts at near saturation. The negative gate pulse cuts the tube off. The inductor dis charges through the capacitor, and oscillations

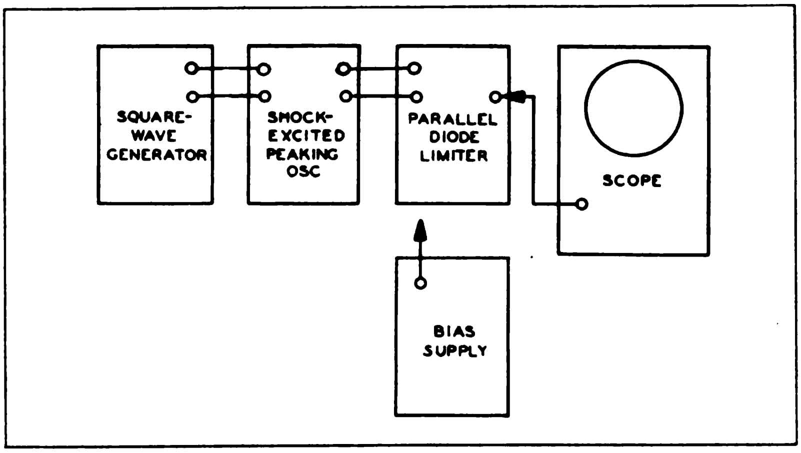


Figure 1. Block Diagram of Equipment Setup for the Shock-Excited Peaking Oscillator Experiment

A. TWO SUCCESSIVE GATE PULSES

B. TWO SUCCESSIVE TRAINS OF DAMPED WAVES
(WITH MINIMUM DAMPING)

C. WAVEFORM RESULTING FROM MAXIMUM DAMPING

D. WAVEFORM AFTER NEGATIVE LIMITING

Figure 2. Waveforms Encountered in the Shock-Excited Peaking Oscillator Experiment

begin, decreasing in amplitude with time because of losses in the resistive components.

2. A lightly damped shock-excited oscillator has a tank circuit that resonates at 50,000 cycles per second. Its output consists of damped wave trains. Each train contains 5 complete cycles, starting with the leading edge of the gate pulse and continuing until the gate pulse disappears. What is the width of the negative gate pulse in microseconds? Show all your work.

Each cycle of 50,000-cycles oscillation requires $\frac{1{,}000{,}000}{50{,}000}$ or 20 μsec., and, since there must be 5 complete cycles per train, the gate must be $5 \times 20 = 100$ μsec. wide.

3. What is meant by "damping"? How is it accomplished in this oscillator?

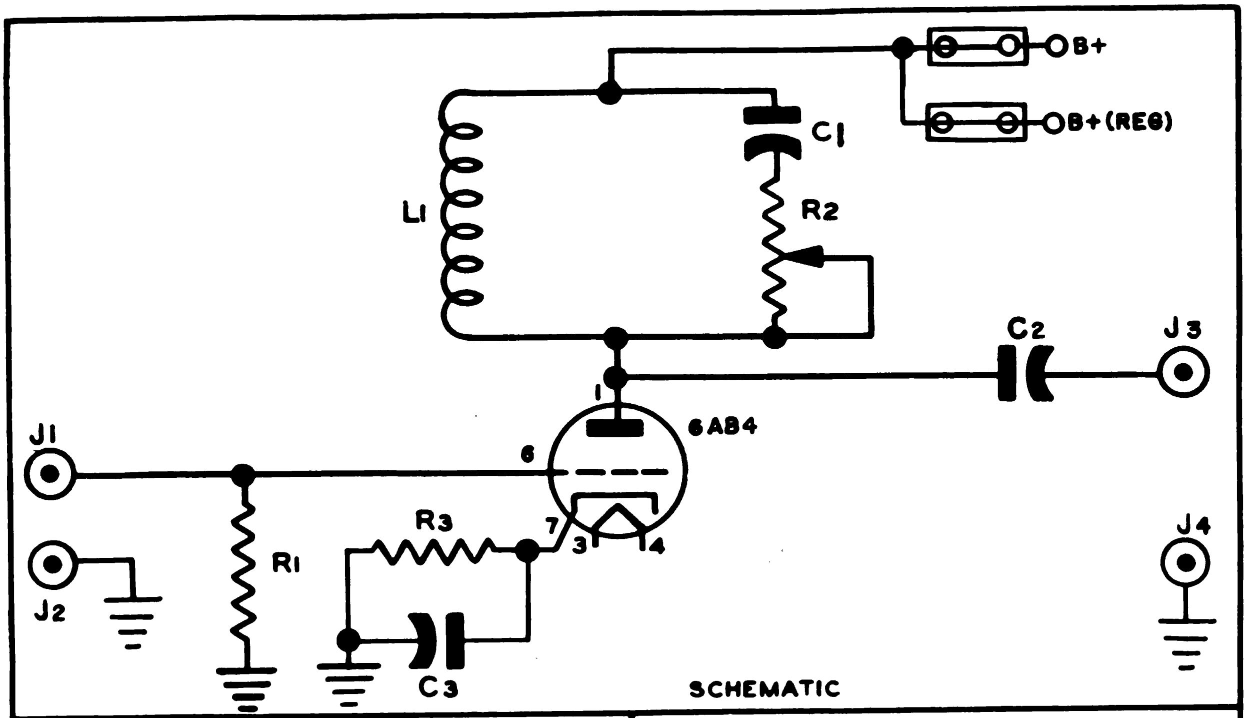
Damping is the reduction in the amplitude of successive oscillations. It is accomplished through the losses in the resistive components in the tank circuit—principally in the variable resistor, R_2.

4. What is meant by "critical damping"? Why is this degree of damping important in a peaking oscillator?

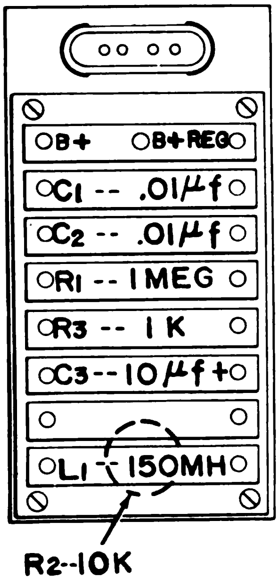
If a circuit oscillates for just one-half cycle, it is critically damped. With this degree of damping, only one peak, of high amplitude and short duration, is produced.

5. Explain the appearance of negative pulses in the waveform drawn at C in figure 2.

The negative pulses are produced when the peaking-oscillator tube starts to conduct. A voltage of opposite polarity is developed across the resonant circuit of the oscillator, since it must oppose the rise of current through the inductor.



R_2—VARIABLE, 10K



Schematic Diagram of Shock-Excited Peaking Oscillator Chassis

LABORATORY PLAN No. 24

SUBJECT

The shock-excited ringing oscillator.

OBJECTIVE

To analyze a shock-excited ringing oscillator; to demonstrate the operation of this circuit when a square-wave trigger is applied; to explain the result of a low Q oscillator tank circuit.

MATERIAL REQUIRED

1. Shock-Excited Ringing Oscillator Chassis.
2. Single-Swing Blocking Oscillator Chassis.
3. Cathode Follower Chassis.
4. One-Shot Multivibrator Chassis.
5. Five-inch oscilloscope, with cross-section screen and leads.
6. Vacuum-tube voltmeter with leads.
7. A-F oscillator with leads.
8. Laboratory Chassis Mounting Rack.
9. Power Supply Chassis.

INTRODUCTION

The shock-excited ringing oscillator is a refinement of the shock-excited peaking oscillator. The damping is reduced to zero, so that oscillations will continue for as many cycles as may be desired. This oscillator can be turned on or off very easily.

SUBJECT MATERIAL

1. Familiarize the class with the Shock-Excited Ringing Oscillator Chassis and its various components.

2. Check the results obtained by the students in making the adjustments called for in the EXPERIMENT. Initial their workbooks when they complete this section.

3. Conduct a brief demonstration, showing the operation of the circuit when used as a keyed ringing oscillator.

4. Briefly demonstrate to the class the effects of varying the tank circuit elements and the effects of damping. Follow the steps given in the EXPERIMENT.

5. Remind the class that all questions in the CONCLUSIONS section of their EXPERIMENT must be completed before the next laboratory session.

CONCLUSIONS

The shock-excited ringing oscillator is useful when a series of sine waves of nearly constant amplitude is needed. The oscillator must be triggered, in order to maintain the oscillations.

EXPERIMENT No. 24

SUBJECT

The shock-excited ringing oscillator.

OBJECTIVE

To test a shock-excited ringing oscillator; to observe the operation of this circuit when a square wave trigger is applied; to study the result of a low Q oscillator tank circuit.

MATERIAL REQUIRED

1. Shock-Excited Ringing Oscillator Chassis.
2. Single-Swing Blocking Oscillator Chassis.
3. Cathode-Follower Chassis.
4. One-Shot Multivibrator Chassis.
5. Five-inch oscilloscope, with cross-section screen and leads.
6. Vacuum-tube voltmeter with leads.
7. A-F oscillator with leads.
8. Laboratory Chassis Mounting Rack.
9. Power Supply Chassis.

INSTRUCTIONS

The shock-excited ringing oscillator is a refinement of the shock-excited peaking oscillator studied in the preceding EXPERIMENT. The peaking oscillator produced an output waveform that was highly damped—the oscillations began at a high amplitude, and died away rapidly.

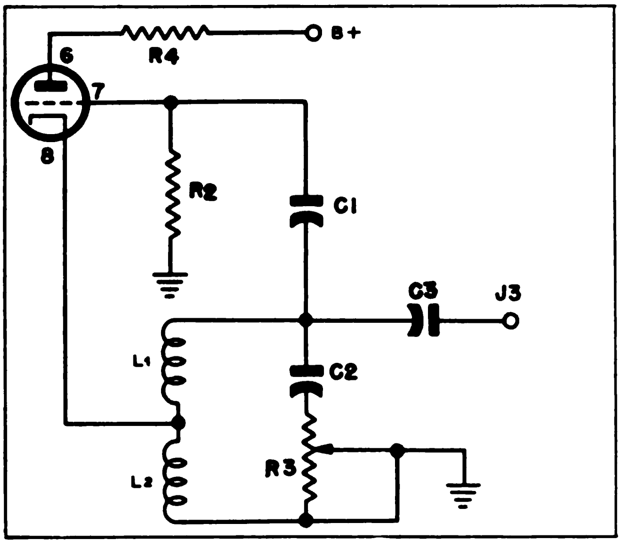
For many uses, it is highly desirable to produce a series of sine waves whose amplitude remains constant, but which can be keyed on and off at regular intervals. The shock-excited ringing oscillator to be studied in this EXPERIMENT makes this type of waveform possible.

The right hand triode acts as a Hartley oscillator. It can produce sinusoidal oscillations at a frequency determined by the LC product of the tank circuit (L1, L2, and C2). This circuit does not normally oscillate, however. It will be noted that tube current of the heavily conducting triode (pins 1, 2, and 3) flows through the oscillator tank coils. As long as this triode conducts heavily, it prevents oscillations.

> NOTE: R4 is a dropping resistor, to limit plate current to a safe value. Its effect can be disregarded when analyzing circuit operation.

When the grid (pin 2) is driven highly negative, however, the "keyer tube" (pins 1, 2, and 3) cuts off. This permits the Hartley oscillator to function, producing continuous oscillations as long as the grid of the keyer tube remains cut off.

In the space provided below, draw a schematic diagram of the circuit as it would exist if the left-hand triode were blocked by a negative gate pulse. Eliminate from your drawing all parts that would not be used.



Equivalent Circuit of the Chassis when a Negative Gate Pulse Is Applied (effectively a Hartley oscillator)

The pulse repetition frequency of this circuit, and the length of time during which the sine-wave oscillations remain keyed in or out, depend upon the shape and size of the "gate pulse" applied to the input jack. Refer to your lecture notes for further information on the operation of this circuit.

PROCEDURE

1. Insert a 100,000-ohm resistor at R1 (grid leak) of the single-swing blocking oscillator.
2. Insert SS-2 in the normal position in the single-swing blocking oscillator.
3. Insert SS-1 and remove SS-1 ALT from the one-shot multivibrator.
4. Connect the equipment as shown in the block diagram, figure 1.
5. Connect the scope lead to the OUTPUT jack (cathode) of the single-swing blocking oscillator. Adjust this oscillator to a frequency of 500 cycles.
6. Connect the scope lead to the OUTPUT No. 1 jack of the one-shot multivibrator, and adjust the potentiometer of the multivibrator

circuit (grid leak) until the widest possible negative gate is obtained.

7. Connect the scope lead to the OUTPUT jack of the shock-excited ringing oscillator. Set the ringing-oscillator potentiometer (damping resistor) at its minimum-resistance position.

8. Vary the width of the gate pulse (by rotating the knob of the one-shot multivibrator potentiometer), and note that cycles can be added to, or removed from, the wave trains.

9. Demonstrate to the instructor the waveforms obtainable, and obtain his approval before proceeding.

Instructor's initials_______

Operation as a Keyed Ringing Oscillator

1. Note that the sine-wave output of a Hartley oscillator is now keyed into groups of sine waves, separated by a straight-line trace. Adjust the damping resistor, R3, until the amplitudes of all cycles within a group are as nearly uniform as possible.

2. Adjust the one-shot multivibrator potentiometer, R6, to produce the narrowest possible gate pulse. (The width of the gate is indicated by the number of sine waves appearing in any one group.)

3. Count and record the number of sine waves transmitted during this narrow gate pulse. Record this pattern at A in figure 2.

Cycles transmitted with narrow gate ___

4. Adjust the one-shot multivibrator potentiometer so as to widen the gate. Note that sine-wave cycles appear, one at a time, at the right-hand end of each group.

5. Count the maximum number of sine waves obtainable with a wide gate. Record this pattern at B in figure 2.

Number of cycles with a wide gate ___

6. Measure the time in microseconds elapsing between the beginning and the end of one group of sine waves, under the following conditions:

a. With the widest gate obtainable, _____

b. With the narrowest gate obtainable, _____

7. Transfer the scope lead to the INPUT jack of the ringing oscillator.

8. Measure the width in microseconds of the gate pulse at its two extremes:

a. The widest gate obtainable, _____

b. The narrowest gate obtainable, _____

9. What connection do you observe between the width of the gate pulse and the length of time during which sine waves are transmitted to the output jack?

They are indentical.

Effects of Varying L and C in Tank Circuit

1. With 10-mh. inductors at L1 and L2, and a .01-μf. capacitor at C2 in the tank circuit, measure the time between adjacent peaks of the sine-wave output of the shock-excited ringing oscillator.

Period of 1 cycle when using 10-mh. inductors tuned by a .01-μf. capacitor, ____ μsec.

2. Change inductors L1 and L2 to 2.5 mh. each. Measure the time between adjacent peaks of the sine-wave output of the shock-excited ringing oscillator.

Period of 1 cycle when using 2.5-mh. inductors tuned by a .01-μf. capacitor, _____ μsec.

3. Replace inductors L1 and L2 with the original values of 10 mh. each, and remove the .01-μf. capacitor at C2. This leaves the tank circuit tuned only by the distributed capacitance of L1 and L2. Measure the time elapsing between adjacent peaks of the sine-wave output of the shock-excited ringing oscillator under these conditions.

Period of 1 cycle when using 10-mh. inductors tuned by distributed capacitance only, _____ μsec.

Effects of Damping

1. Reinsert the original parts.

2. Turn the ringing oscillator potentiometer, R3, to its minimum-resistance position. At C in figure 2, sketch the waveform obtained at the OUTPUT jack of the ringing oscillator. Measure the average peak-to-peak amplitude, and enter this figure on the sketch.

3. Turn the potentiometer to mid-scale, and sketch, at D in figure 2, the waveform obtained. Measure the average peak-to-peak amplitude, and enter this figure on the sketch.

4. Turn the potentiometer toward its high-resistance position until the sine-wave trace almost disappears. Sketch the trace obtained at E in figure 2. Measure the average peak-to-peak amplitude, and enter this figure on the sketch.

5. Compare the results obtained with the ringing oscillator with those obtained from the shock-excited peaking oscillator when resistance is inserted in the tank circuit.

CONCLUSIONS

1. At figure 3, draw a representative gate pulse and the resultant sine-wave output waveforms in the positions indicated. Be careful to place these traces in proper phase relationship with each other.

2. Write a concise explanation of what takes place in the shock-excited ringing oscillator when it is keyed by a square-wave trigger pulse.

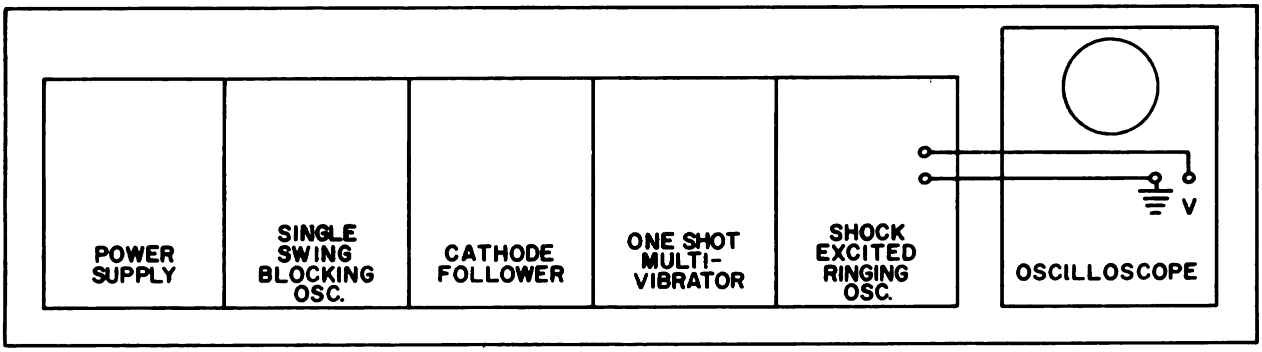


Figure 1. Block Diagram of Equipment Setup for the Shock-Excited Ringing Oscillator Experiment

When V1A is driven to cutoff, V1B oscillates as a Hartley oscillator. When the gate goes positive, V1A conducts, and loads V1B to the point where it does not oscillate.

3. Refer to step 3 under Effects of Varying L and C in Tank Circuit. Calculate the effective capacitance (distributed and stray) that must be present when the tuning capacitor, C2, is removed, in order to produce the frequency observed. Show all your work.

Sample Problem:

Let us suppose, from step 3 under Effects of Varying L and C in Tank Circuit, the period of one cycle, when C2 is removed (leaving only the distributed and stray capacitance in the circuit) is 16.7 microseconds. Hence, the frequency, being the reciprocal of the pulse width, is 60,000 cycles. Single frequency in a tank circuit is $f = \frac{1}{2\pi\sqrt{LC}}$, the equation may be rearranged to solve for C. Hence, $C = \frac{1}{4\pi^2 f^2 L}$ where L is 20 millihenries. Therefore:

$$C = \frac{1}{4\pi^2 f^2 L} = \frac{1}{4\,(3.14)^2\,(60\times10^3)^2\,(20\times10^{-3})}$$

$= 351.6\ \mu\mu f.$

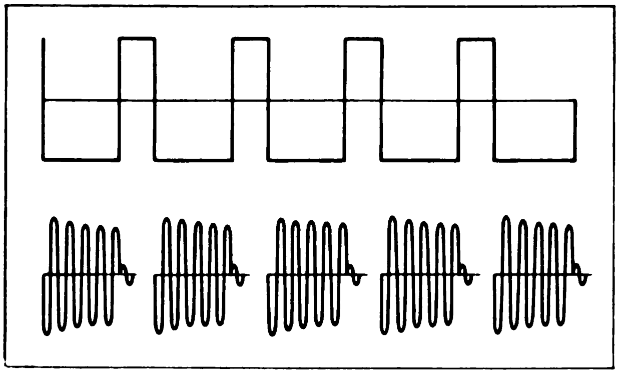


Figure 3. Synchrogram of Waveform Encountered in Shock-Excited Ringing Oscillator

4. Discuss the effect of tank-circuit L and C upon the width of the pulses.

They have no effect. Pulse width depends entirely upon the width of the negative gate.

5. In a later EXPERIMENT, it will become necessary to generate range-marker pips that are 10 miles (122 microseconds) apart. This will be accomplished by using a ringing oscillator to produce sine waves whose peaks are separated by 122 microseconds, and then shaping these sine waves into positive pips. Calculate the total inductance that must be included in the ringing-oscillator tank circuit if the tank is tuned by a .01-μf. capacitor. Show all your work.

Frequency is the reciprocal of pulse width in microseconds. Hence, frequency is $1/122\times10^{-6} = 8196$ cycles. The tank circuit is resonant at this frequency, and this frequency is given by the formula,

$$f = \frac{1}{2\pi\sqrt{LC}}.$$

This equation may be rearranged to solve for L; hence $L = \frac{1}{4\pi^2 f^2 C}$ where C is .01 μf. Therefore:

$$L = \frac{1}{4\pi^2 f^2 C} = \frac{1}{4\,(3.14)^2\,(8196)^2\,(.01\times10^{-6})}$$

$= 37.23$ mh.

A
RINGING-OSCILLATOR WAVE TRAIN, USING A NARROW GATE

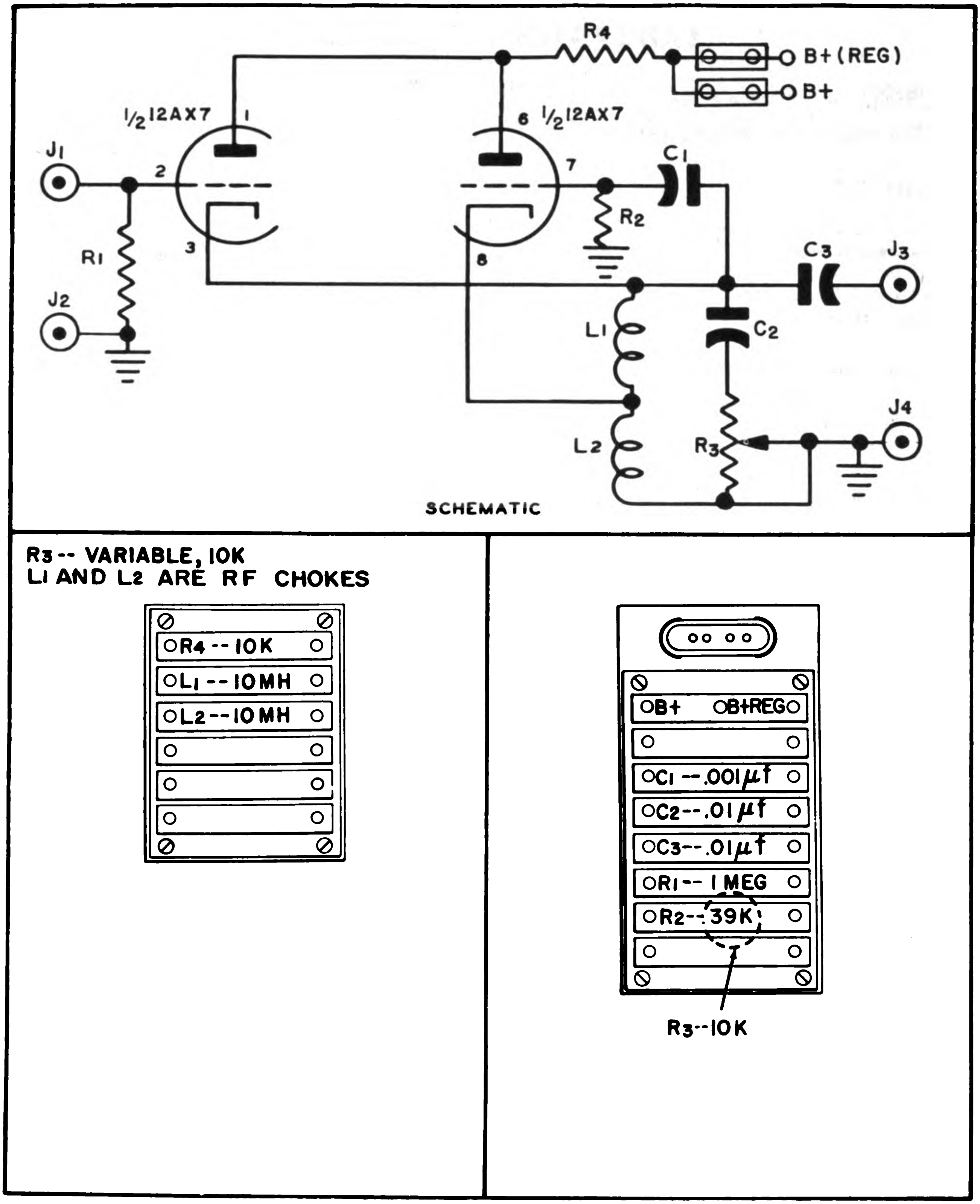
B
RINGING - OSCILLATOR WAVE TRAIN, USING A WIDE GATE

C
RINGING - OSCILLATOR WAVE TRAIN, WITH MINIMUM DAMPING

D
RINGING - OSCILLATOR WAVE TRAIN, WITH MODERATE DAMPING

E
RINGING - OSCILLATOR WAVE TRAIN, WITH HEAVY DAMPING

Figure 2. Waveforms Obtained from a Ringing Oscillator under Various Conditions



R3 -- VARIABLE, 10K
L1 AND L2 ARE RF CHOKES

Schematic Diagram of Shock-Excited Ringing Oscillator Chassis

LABORATORY PLAN No. 25

SUBJECT

The single-swing blocking oscillator.

OBJECTIVE

To explain the operation of the single-swing blocking oscillator; to conduct the observation and measurements of the waveforms developed; and to clarify the method of synchronization used in the circuit.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis.
2. Triode Limiter Chassis.
3. Five-inch oscilloscope, with leads and cross-section screen.
4. A-F oscillator with leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Additional plug-in parts as follows:
   Resistor, 100,000 ohms.
   Capacitor, .0001 μf.
8. Power Supply Chassis.

INTRODUCTION

A blocking oscillator is characterized by the fact that it cuts itself off after one or more cycles of oscillation, due to the accumulated negative charge on the grid capacitor. The single-swing blocking oscillator cuts itself off during, or at the end of, one cycle of oscillation.

SUBJECT MATERIAL

1. Show the class the proper waveforms which should be obtained from the plate and cathode.
2. Be sure the class understands thoroughly the importance of the grid capacitor and grid-leak resistor in determining the repetition frequency of the oscillator.
3. Supervise the process the student uses to apply the synchronizing voltages to the oscillator.

CONCLUSIONS

The single-swing blocking oscillator is an important and useful circuit for the generation of narrow width pulses. These pulses are entirely positive, and have a very stable pulse repetition frequency. The oscillator is often employed in the audio-frequency section of radar systems.

EXPERIMENT No. 25

SUBJECT

The single-swing blocking oscillator.

OBJECTIVE

To study the circuit operation of the single-swing blocking oscillator; to observe and make measurements upon the waveforms developed in such an oscillator; to study the process of synchronizing this type of oscillator.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis.
2. Triode Limiter Chassis.
3. Five-inch oscilloscope, with cross-section screen and leads.
4. A-F oscillator with leads.
5. Vacuum-tube voltmeter with leads.
6. Laboratory Chassis Mounting Rack.
7. Additional plug-in parts as follows:
   Resistor, 100,000 ohms.
   Capacitor, .0001 μf.
8. Power Supply Chassis.

INSTRUCTIONS

The circuit of a single-swing blocking oscillator will be investigated in this EXPERIMENT.

The student will observe the waveforms developed at the plate and at the cathode of the tube. He will note that this oscillator, when properly adjusted, produces at the plate a single cycle of nearly sinusoidal output voltage, followed by a long "resting" period, during which no voltage is generated. He will note the difference between the frequency of the voltage variations in this single sine-wave pulse and the rate at which the pulse is repeated (pulse repetition frequency). He will observe that cathode current flows in narrow positive pulses. Finally, he will study the process by which the pulse repetition frequency of the blocking oscillator can be synchronized by a sine-wave voltage applied to the grid circuit of the tube.

PROCEDURE

Connection of Equipment

1. Make sure that the shorting strip SS-1 is in place and SS-2 is in alternate position, in the single-swing blocking oscillator.

2. Plug in the single-swing blocking oscillator adjacent to the power supply, leaving two spaces at the left.

3. Leave the a-f oscillator disconnected, temporarily.

Plate Waveform

1. Turn on the equipment and adjust R2 and the oscilloscope for 3 cycles.

2. Measure and record the peak positive and the peak negative amplitudes of the single-swing plate variations.

Positive peak _____ volts.
Negative peak _____ volts.

3. Measure and record the width of the positive alternation. Use the method described in the INFORMATION SHEET on time measurements by means of a linear sweep.

Positive pulse width _____ microseconds.

4. Sketch the waveform in Figure 1.

Cathode Waveform

1. Move SS-2 to its normal position to observe the cathode waveform.

2. Adjust the scope to display a line of positive pulses.

3. Measure and record the peak amplitude of the pulses.

Peak amplitude _____ volts.

4. Measure and record the pulse width at the base line.

Pulse width _____ microseconds.

5. Sketch the waveform observed, in figure 1.

Parts Affecting Repetition Frequency

Grid Leak

1. Using the .001-μf. grid capacitor already at C1, vary the grid-leak (potentiometer R2) from its maximum-resistance position to its minimum-resistance position.

2. Measure and record the range of repetition frequencies obtained:

With maximum grid-leak resistance, _____ pulses/sec.

With minimum grid-leak resistance, _____ pulses/sec.

Grid Capacitor

1. Remove the .001-μf. grid capacitor at C1, and insert a .0001-μf. capacitor.

2. Vary the grid-leak potentiometer from its maximum-resistance position to its minimum-resistance position.

3. Measure and record the range of repetition frequencies obtained:

With maximum grid-leak resistance, ______ pulses/sec.

With minimum grid-leak resistance, ______ pulses/sec.

Synchronization

1. In the Triode Limiter Chassis, remove grid-limiting resistor R2, and replace it with a shorting strip. This converts the chassis for use as a conventional voltage amplifier.

2. Remove shorting strip SS1 in the Single-Swing Blocking Oscillator Chassis, and insert a 100,000-ohm resistor.

3. Insert the triode limiter at the left of the oscillator and connect the vertical lead of the scope to the INPUT jack of the single-swing blocking oscillator.

Blocking Oscillator Grid Waveform

1. Adjust the blocking-oscillator grid-leak potentiometer, R2, and the frequency control of the scope until a series of negative pulses appears on the scope screen.

2. Observe the waveform produced, and record it at A in figure 2. Note that R2 still controls the repetition frequency.

3. Measure the frequency of the grid-voltage waveform being generated by the blocking oscillator. Record this frequency in the space provided at A in figure 2. Leave R2 at its present setting.

4. Connect the a-f oscillator to the INPUT jack of the Triode Limiter Chassis. Set the frequency of the a-f oscillator to the frequency recorded at A in figure 2. The a-f oscillator now controls the repetition frequency.

5. Observe the waveform produced, and record it at B in figure 2. In the space provided at B in figure 2, record the frequency indicated on the a-f oscillator dial.

6. Turn the knob of the blocking-oscillator grid-leak potentiometer first to one side of its present setting, then to the other. Note that the knob can be rotated over a considerable arc before the scope trace becomes unstable. Explain why.

The blocking oscillator is being synchronized by the audio-frequency oscillator. Hence, its operation is stable.

7. Set the a-f oscillator dial for approximately twice the frequency recorded at B in figure 2. Then vary the setting of this dial slowly until the negative pulses appear on alternate sine waves, leaving every second sine wave without a negative pulse. Make slight readjustments to the scope frequency controls, if necessary. Record the observed waveform at C in figure 2.

8. Explain what is happening in the circuit to produce the waveform observed in step 7, above.

During the oscillation of the single-swing blocking oscillator, the grid capacitor charges to a very high negative value. For the stage to oscillate, the voltage on the grid must relax to a small negative value, cutoff. The sum of the voltage on the capacitor and the sinusoidal synchronizing voltage, therefore, must equal the cutoff voltage before the circuit will operate. On the first cycle of the synchronizing voltage, the capacitor does not discharge to the point where the synchronizing voltage can trigger the tube. The triggering point is reached, however, at some instant during the second synchronizing pulse, and the tube fires at that time.

9. Set the a-f oscillator dial for approximately three times the frequency recorded at B in figure 2. Make slight adjustments until a negative pulse appears upon every third sine wave. Record this waveform at D in figure 2.

10. Explain the circuit action which produces the waveform observed in step 9, above.

During the oscillation of the single-swing blocking oscillator, the grid capacitor charges to a very high negative value. For the stage to oscillate, the voltage on the grid must relax to a voltage slightly more positive than cutoff, some small negative value. The sum of the voltage on the capacitor and the sinusoidal synchronizing voltage, therefore, must equal the cutoff voltage before the stage will oscillate. On the first two cycles of the synchronizing voltage, the capacitor does not discharge to the point where the sync voltage can trigger the tube.

CONCLUSIONS

1. b. Why is a transformer employed in the single-swing blocking oscillator? (Choose the correct answer.)

a. To couple the output of the oscillator to the succeeding stage.

b. To provide feedback.

c. As a step-up transformer, to increase the output voltage.

d. As a filter for the synchronizing voltage.

2. At figure 3, draw the plate-voltage and the cathode-current waveforms of the blocking oscillator. Be careful to show them in correct phase relationship with each other.

3. d. What is the purpose of cathode resistor R3 in the blocking oscillator? (Choose the correct answer.)

a. To prevent surges of current in the oscillator tube.

b. To bias the tube to cutoff.

c. To convert the circuit to a cathode follower.

d. To develop a positive output voltage.

4. Explain why varying R2 can cause the output voltage waveform of the blocking oscillator to be erratic, even though a synchronizing voltage is being applied.

5. a, e. What will happen in a free-running blocking oscillator if R2 is changed to a low-resistance position? (Choose the correct answer.)

a. The repetition frequency will increase.

b. The frequency of the individual sine waves will increase.

c. The repetition frequency will decrease.

d. The peak voltage on the grid capacitor (C1) will decrease.

e. The slope of the grid-voltage waveform will increase.

PLATE WAVEFORM	CATHODE WAVEFORM

Figure 1. Waveforms Developed in Single-Swing Blocking Oscillator

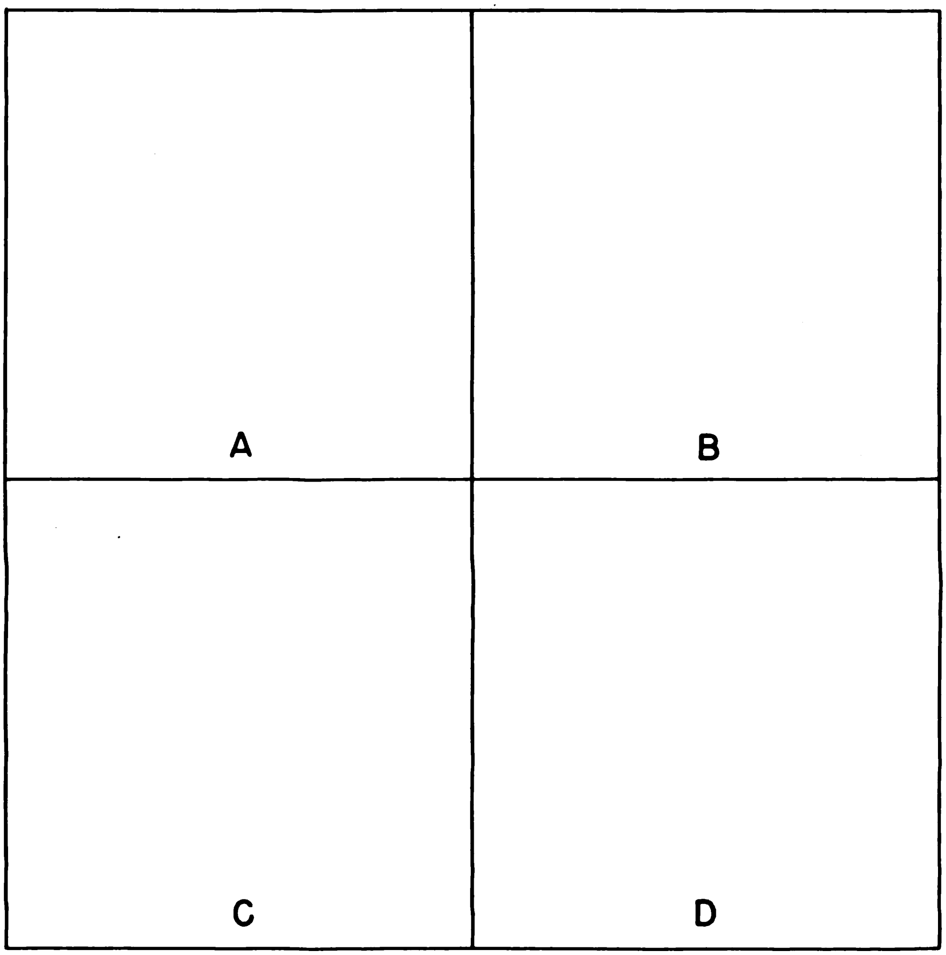
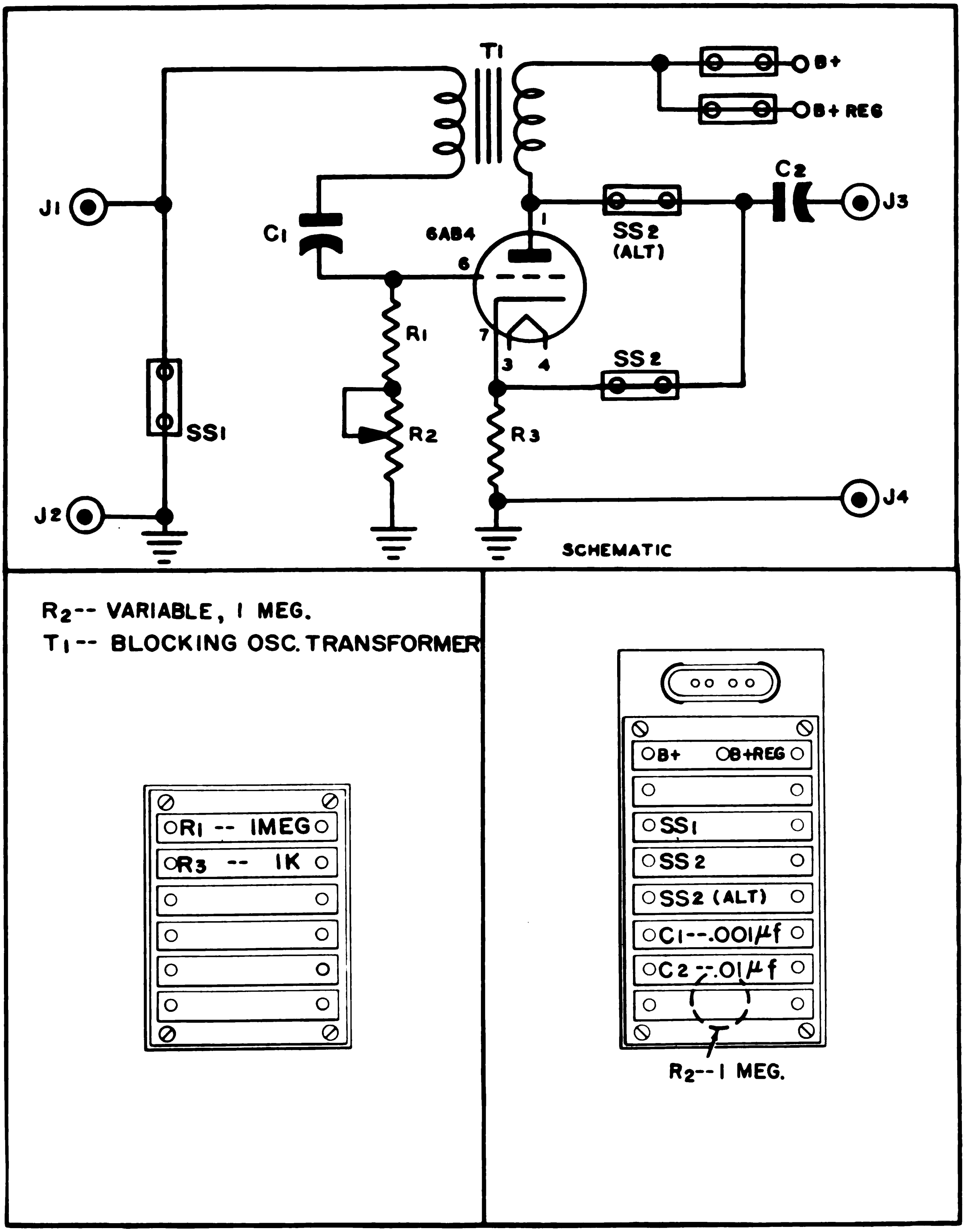


Figure 2. Grid Waveforms, Showing How Synchronization Is Accomplished

Figure 3. Plate-Voltage and Cathode-Current Waveforms in Single-Swing Blocking Oscillator



Schematic Diagram of Single-Swing Blocking Oscillator Chassis

LABORATORY PLAN No. 26

SUBJECT

The step counter.

OBJECTIVE

To supervise the testing, and operational check of the step-counter circuit.

MATERIAL REQUIRED

1. Step Counter Chassis.
2. Triggered Blocking Oscillator Chassis.
3. Single-Swing Blocking Oscillator Chassis.
4. Cathode Follower Chassis.
5. One-Shot Multivibrator Chassis.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.
8. Five-inch oscilloscope with leads.
9. Vacuum-tube voltmeter with leads.

INTRODUCTION

The purpose of the step counter is to produce an output voltage whose frequency is some submultiple of the input frequency. As such, it acts like a frequency-dividing device in which the only variable is the pulse repetition frequency.

SUBJECT MATERIAL

1. Supervise the testing of both the Step Counter Chassis and the Triggered Blocking Oscillator Chassis.

2. Perform a brief demonstration, indicating the results to be expected in the EXPERIMENT. Refer to the EXPERIMENT, and follow the steps given there.

3. Be certain that the waveforms obtained by each group are accurate, and are neatly and carefully drawn. An understanding of the operation of the circuit may be derived from the waveforms produced.

4. Remind the class that the completed EXPERIMENT is to be turned in for grading during the laboratory session following the completion of this EXPERIMENT.

CONCLUSIONS

Input voltage to the step counter is produced by a chain of radar chassis such as that previously used. The chain consists of the single-swing blocking oscillator, the cathode follower, and the one-shot multivibrator. The output of this chain will be a series of uniformly spaced rectangular "gate pulses," whose repetition frequency may be adjusted to a desired value.

The step counter has a few peculiarities, some of which are:

a. The circuit operates best over a narrow frequency range, for any one combination of counting capacitors.

b. The adjustment of the triggered blocking oscillator is fully as important to the over-all operation as is the ratio of the counting capacitors, C1 and C2, in the step-counting chassis.

c. In case of improper operation, both chassis must be suspected, and the defective chassis can be located by trouble shooting, using a logical process already studied.

EXPERIMENT No. 26

SUBJECT

The step counter.

OBJECTIVE

To test a step counter; to study the waveforms produced; and to determine which parts affect step-counting.

MATERIAL REQUIRED

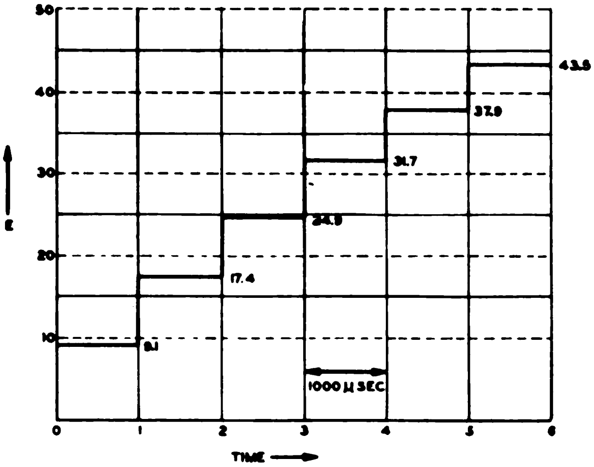
1. Step Counter Chassis.
2. Triggered Blocking Oscillator Chassis.
3. Single Swing Blocking Oscillator Chassis.
4. Cathode Follower Chassis.
5. One-Shot Multivibrator Chassis.
6. Laboratory Chassis Mounting Rack.
7. Power Supply Chassis.
8. Five-inch oscilloscope with leads.
9. Vacuum-tube voltmeter with leads.

INSTRUCTIONS

The student is already familiar with frequency-multiplier circuits, such as the frequency doublers and triplers used in radio transmitters. Their purpose is to produce an output voltage having a frequency of two or three (or some other integral number) times as high as the frequency of the input voltage.

The step counter to be studied in this EXPERIMENT does the exact opposite. It produces an output voltage having a frequency ½ or ⅓ (or some other fraction) of the frequency of the input voltage. It is, for example, capable of accepting an input signal of 1000 cycles per second, and producing an output voltage with a frequency of 250, 200, 167, or 143 cycles per second. The step counter, for this reason is also called a "frequency-divider" circuit. It divides the input frequency by 4, 5, 6, or 7.

Input voltage to the step counter will be produced by a chain of the radar chassis already studied by the student. This chain will consist of the single-swing blocking oscillator, the cathode follower, and the one-shot multivibrator. The output of this chain will be a series of uniformly spaced rectangular "gate pulses," whose repetition frequency can be adjusted to a desired value. The student will observe that for every 4, 5, 6, or 7 input gate pulses, there will be one output pulse from the step-counter circuit. The exact number of "steps" (4, 5, 6, or 7) can be selected by varying R4 of the triggered blocking oscillator or by changing certain plug-in parts in the step counter.



Waveform Developed in the Step-Counter Circuit

The step-counter circuit consists of two separate chassis. The first, which does the actual counting, will be referred to as the Step Counter Chassis; it comprises a double-diode tube and two capacitors. The second part will be known as the Triggered Blocking Oscillator Chassis. The step-counting operation requires the use of both chassis, connected together as a unit.

PROCEDURE

1. Obtain the items listed under MATERIAL REQUIRED.

CAUTION:
TO PERFORM THIS EXPERIMENT, REMOVE R2 ENTIRELY AND REPLACE R1 WITH A SHORTING STRIP IN THE TRIGGERED BLOCKING OSCILLATOR.

2. Set up the single-swing blocking oscillator, the cathode follower, the one-shot multivibrator, the step counter, the triggered blocking oscillator and the power supply in the rack, in that order.

3. Observe and record the waveforms according to the procedure given below.

Output of Single Swing Blocking Oscillator

1. Insert SS-1 and SS-2 in normal positions in the single swing blocking oscillator.

2. Connect the vertical scope lead to the OUTPUT jack of the Single-Swing Blocking Oscillator Chassis.

3. Adjust the single-swing blocking oscillator and the scope to display 5 or 6 cycles of the output waveform (positive pulses).

4. Draw these pulses accurately at A in figure 1.

Output of One Shot Multivibrator

1. Place SS-1 in normal position in this multivibrator.

2. Transfer the vertical scope lead to the TOP OUTPUT jack of the One-Shot Multivibrator Chassis. The resulting trace should be a group of six positive-going rectangular gate pulses.

3. Adjust the multivibrator potentiometer until these pulses are as narrow as is consistent with good stability.

4. Draw the gate pulses accurately at B in figure 1. Place the leading edges of the gate pulses directly beneath the leading edges of the trigger pulses drawn at A.

Output of Step Counter

1. Transfer the vertical scope lead to the OUTPUT jack of the Step Counter Chassis. Make adjustments of the scope frequency controls until the pattern remains stationary. If the trace is jittery, make slight adjustments of the triggered-blocking-oscillator potentiometer. The scope should display a flight of stairsteps.

2. Draw the steps accurately at C in figure 1. Place the leading edges of the steps directly beneath the leading edges of the gate pulses drawn at B.

Output of Triggered Blocking Oscillator

1. Transfer the vertical scope lead to the OUTPUT jack of the Triggered Blocking Oscillator Chassis. A single pulse should appear on the scope.

2. Draw this pulse accurately at D in figure 1. Place the leading edge of the pulse directly beneath the leading edge of the last (right-hand) step drawn at C.

The synchrogram (figure 1) now shows how the original pulses from the single-swing blocking oscillator (A) have been converted into gate pulses of the same frequency (B), and have then been "counted down" (C) until they emerge from the triggered blocking oscillator as pulses of a much lower frequency (D). Measure and record the input and output frequencies of this chain (measure at the outputs of the single-swing blocking oscillator and the triggered blocking oscillator, respecitvely):

Input pulse repetition frequency, _____ pulses/sec.

Output pulse repetition frequency, _____ pulses/sec.

Input p.r.f./output p.r.f. _____

Parts Affecting Frequency Division

Bias Resistor of Triggered Blocking Oscillator

1. With the vertical scope lead connected to the OUTPUT jack of the triggered blocking oscillator (producing the waveform shown in D of figure 1), vary the oscillator potentiometer over its entire range. Note that the number of steps changes.

2. Describe these changes using the following questions as a quide:

a. What is the greatest and the smallest number of steps obtainable?

b. Does increasing the cathode bias of the triggered blocking oscillator increase or decrease the number of steps?

Discharging Capacitor (C1), of Step Counter Chassis.

1. With the vertical scope lead connected to the OUTPUT jack of the step counter, count and record the number of steps (the factor by which the frequency will be divided).

_____steps

2. Change the .01-μf. capacitor, C1, to .1-μf. Count and record the number of steps produced.

_____steps

3. Change capacitor C1 to .001 μf. Count and record the number of steps produced.

_____steps

4. Explain briefly why a change in capacitor C1 will produce a change in the number of steps.

5. Replace capacitor C1 with the original value of .01 μf.

Charging Capacitor (C2) of Step Counter Chassis

1. With the vertical scope lead connected to the OUTPUT jack of the step counter, count and record the number of steps produced.

_____steps

2. Change the .1-μf. capacitor, C2, to .22 μf. Count and record the number of steps produced.

_____steps

3. Replace capacitor C2 with the original value of .1 μf.

4. In the space provided below, explain why a higher value of capacitance will produce a greater number of steps, with improved linearity.

More steps will be required because the same diode current will cause a smaller increase in the voltage. The steps will be more linear because the increments will be smaller.

CONCLUSIONS

1. Explain, in your own words, how the step-counter circuit (Step Counter Chassis and Triggered Blocking Oscillator Chassis) used in this EXPERIMENT produces an output voltage whose frequency is lower than that of the input voltage.

On positive input swings, capacitors C1 and C2 are partially charged. On negative input swings, C1 discharges through the parallel section of the tube, and, since there is no discharge path for C2, it maintains its charge. On each successive positive swing, the process repeats until the charge on C2 is great enough to trigger the single-swing blocking oscillator. This action shorts out C2, discharging it. The cycle then repeats, resulting in the oscillator being triggered once out of several input cycles. In this manner, the output frequency is made lower than that of the input.

2. A step-counter circuit is divided by 4, thereby reducing a 1000-cycle input signal to 250 cycles at the output. It is desired to produce a 200-cycle output signal. In the space below, name two changes in circuit constants that would make this possible. (The values of the components are not required: merely specify whether the parts values should be made larger or smaller).

a. Make C1 smaller.
b. Make C2 larger.

3. In this exercise you will calculate data for a graph of the output waveform of a step-counter circuit, based upon certain assigned circuit characteristics. From this graph you will be able to determine the bias voltage required to produce frequency reduction of any desired ratio. Assume that the gate pulses of the step-counter circuit have a peak amplitude of 110 volts, and a pulse repetition frequency of 1000 pulses per second. Let C1 and C2 have capacitances of .001 and .01 μf., respectively, and assume that the diodes have negligible resistance when conducting. Let the cutoff grid voltage of the blocking oscillator tube be -22 volts.

The TABLE OF VOLTAGES, when completed, will show the changes in the various potentials in this step-counter circuit as successive gate pulses are applied to the input. As a guide, computed values are supplied for the first two gate pulses of the counting cycle; these are the results of computations in the paragraphs immediately following. You will make the calculations for the remaining four gate pulses, and will enter the results in the table. From this data you will prepare a graph of voltage across charging capacitor C2 as a function of time in microseconds.

From the graph, determine how much bias must be applied to the cathode of the triggered blocking oscillator to make the circuit "count down" in steps of 5.

Cathode bias _____ volts

The bias applied to the cathode of the blocking oscillator is equal to the sum of the cutoff grid voltage of the tube (-22 volts) and the voltage on capacitor C2 when the circuit is "counting down" in steps of five (found to be 37.9 volts in the table). Hence, the total bias is the sum of 22 and 37.9 volts, or 59.9 volts.

The first step to appear on the graph starts at

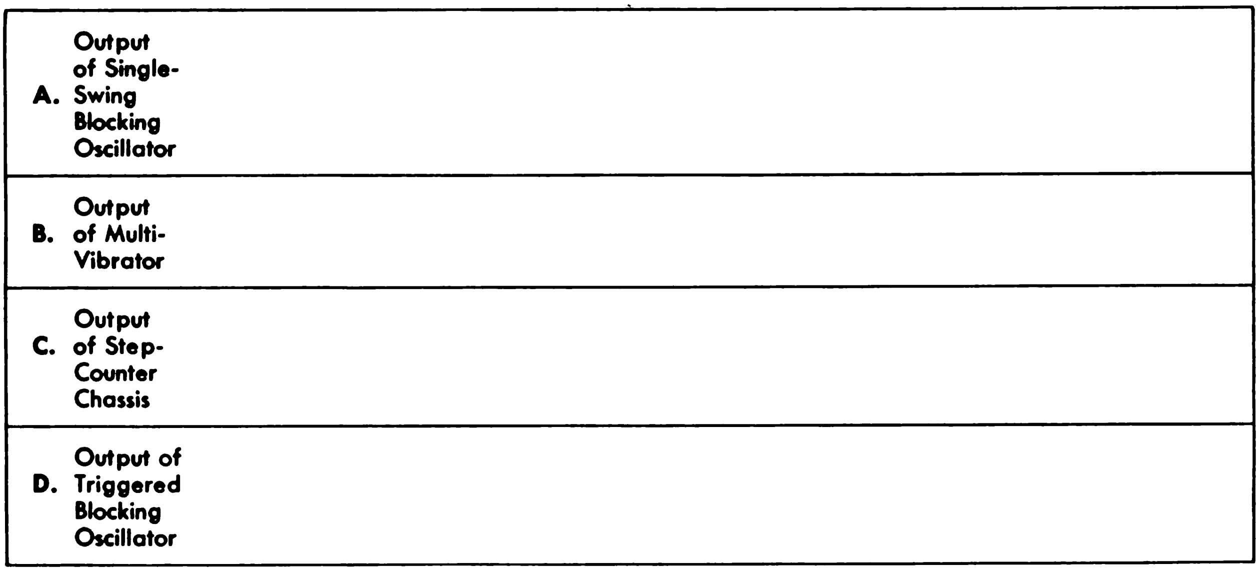

A. Output of Single-Swing Blocking Oscillator
B. Output of Multi-Vibrator
C. Output of Step-Counter Chassis
D. Output of Triggered Blocking Oscillator

Figure 1. Synchrogram of Waveforms Developed in a Step-Counter Chain

zero voltage, since no external bias is supplied, and it is assumed that the circuit bias has not been in operation for some time. Just before the leading edge of the first gate pulse arrives, there is no voltage on either C1 or C2, or across the input terminals. As the gate pulse reaches its peak, the full 100 volts is applied across C1 and C2, in series. Since the capacitance of C2 is 10 times as large as that of C1, C2 will receive 1/11 of the total voltage, or 100/11 = 9.1 volts. At the end of the first gate pulse, therefore, the condition is as follows:

Voltage across C2— 9.1 volts
Voltage across C1—90.9 volts

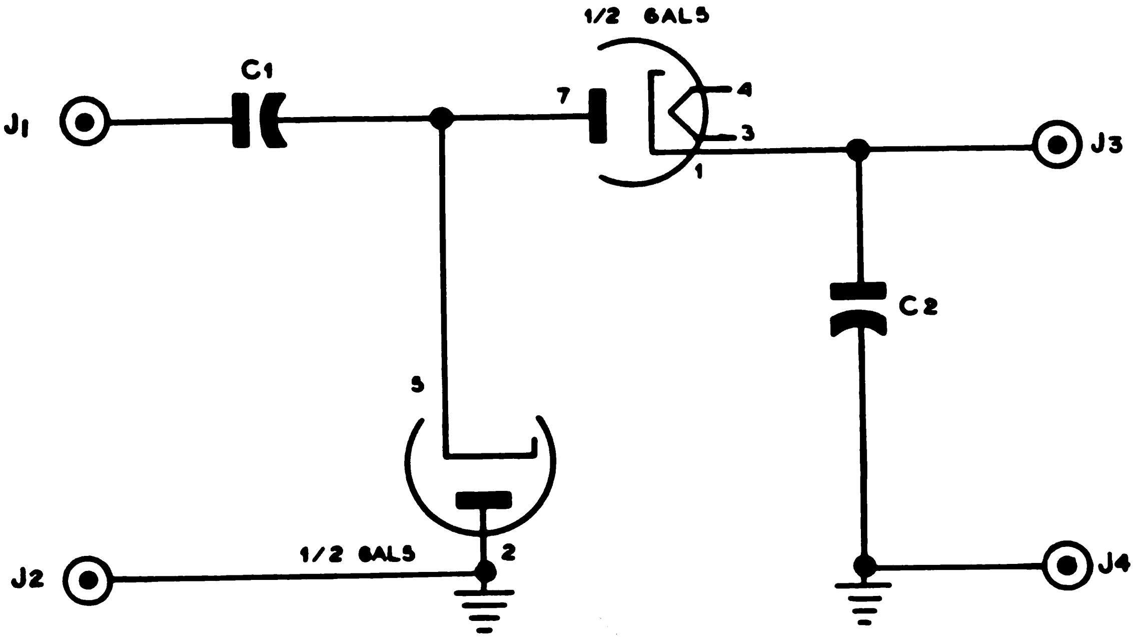
The second step of the graph is built upon the first. Just before the leading edge of the second gate pulse arrives, it will be found that there is zero voltage across C1. This condition is achieved during the long interval when the input voltage is negative; the left-hand diode is, therefore, conducting, and this is draining away to ground the 90.9-volt charge on C1. By the time the second gate pulse arrives, this charge is dissipated, and C1 is uncharged. However, the 9.1-volt charge placed upon C2 by the first gate pulse remains.

As the second gate pulse reaches its peak, 100 volts is once more applied across C1 and C2, in series. But this time, this voltage is opposed by that due to the charge on C2—a potential of 9.1 volts—which is subtracted from the new applied voltage, reducing it to 100 − 9.1, or 90.9 volts. Once more, C2 will drop 1/11 of the resulting effective applied voltage; 90.9/11 = 8.3 volts. This 8.3-volt potential will be added to the 9.1 volts already existing across C2, bringing the total voltage across C2 to 17.4 volts. Since the total applied voltage is 100 volts, this leaves 100 − 17.4 = 82.6 volts across C1. At the end of the second gate pulse, therefore, the condition is as follows:

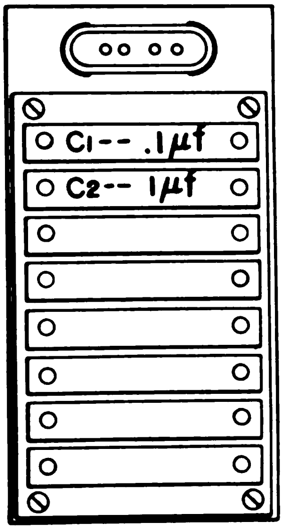
Voltage across C2—17.4 volts
Voltage across C1—82.6 volts

You should now be able to make similar calculations for the voltages existing at the start and at the end of any subsequent gate pulse.

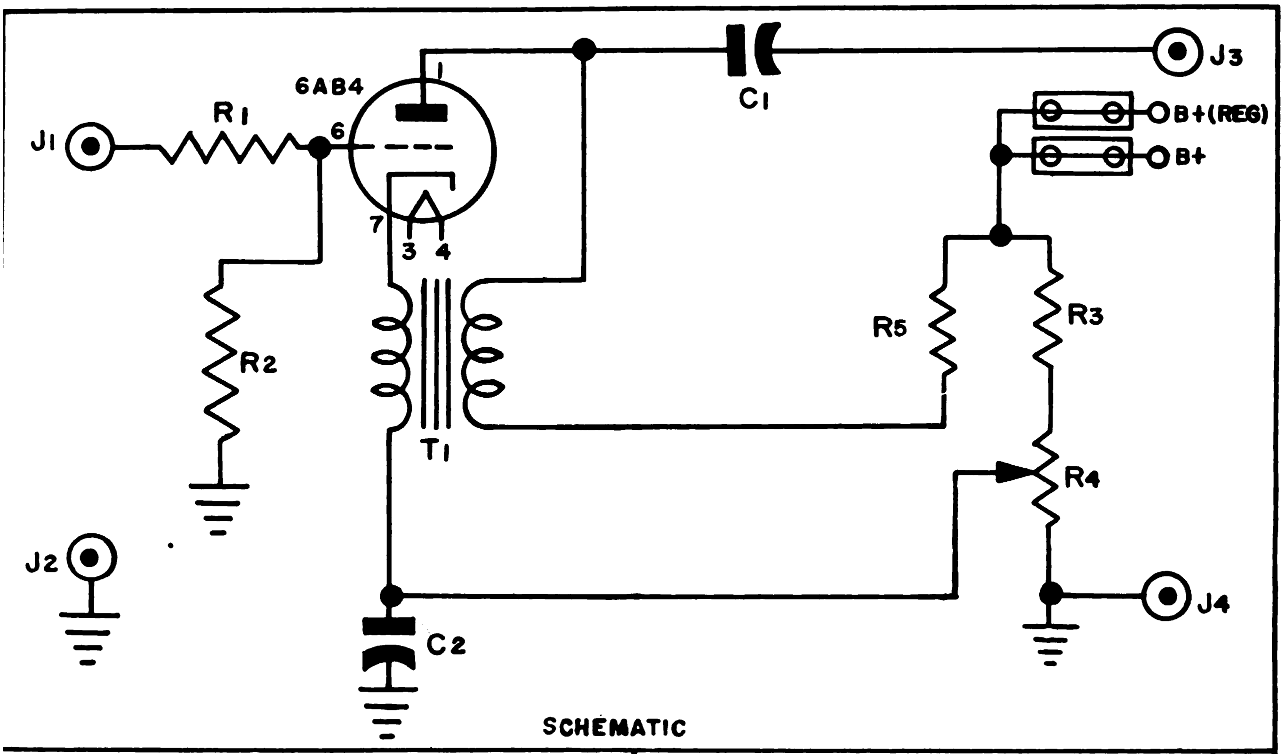
GATE PULSE No.	INSTANT OF MEASUREMENT	EFFECTIVE VOLTS, INPUT TO GROUND (E_{in}—E_{C2})	INCREASE IN C2 VOLTS	C2 VOLTS	C1 VOLTS
1	Start	0		0	0
	End	100	9.1	9.09	90.9
2	Start	0		9.1	0
	End	90.9	8.3	17.4	82.6
3	Start	0		17.4	0
	End	82.6	7.5	24.9	75.1
4	Start	0		24.9	0
	End	75.1	6.8	31.7	68.3
5	Start	0		31.7	0
	End	68.3	6.2	37.9	62.1
6	Start	0		37.9	0
	End	62.1	5.6	43.5	56.5



SCHEMATIC

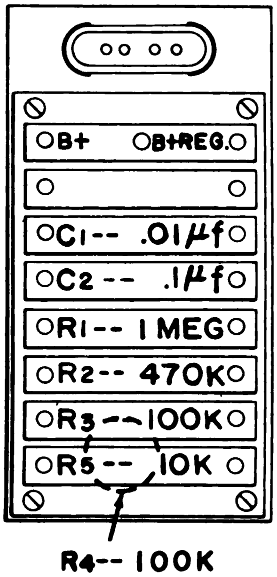


Schematic Diagram of Step Counter Chassis



SCHEMATIC

R4 -- VARIABLE, 100K
T1 --BLOCKING OSC. TRANSFORMER



Schematic Diagram of Triggered Blocking Oscillator Chassis

LABORATORY PLAN No. 27

SUBJECT

The thyratron saw-tooth generator.

OBJECTIVE

To supervise the testing and operational check of the thyratron saw-tooth generator.

MATERIAL REQUIRED

1. Thyratron Saw-tooth Generator Chassis.
2. Five-inch oscilloscope with leads.
3. Power Supply Chassis.
4. Laboratory Chassis Mounting Rack.
5. Cathode Follower Chassis.
6. A-F oscillator with leads.
7. Vacuum-tube voltmeter with leads.
8. Bias Supply Chassis.

INTRODUCTION

This saw-tooth generator is capable of producing a wide range of sweep frequencies. Because of this flexibility of frequency range, thyratrons are widely used in the sweep circuits of oscilloscopes.

SUBJECT MATERIAL

1. Have the students make the measurements outlined in the EXPERIMENT, and record them. Be sure these measurements are correct.

2. For the benefit of the students, produce the correct waveforms, as called for in the EXPERIMENT. Then have the students produce the waveforms.

CONCLUSIONS

The student should, at the completion of this EXPERIMENT, be thoroughly acquainted with the thyratron saw-tooth generator and the wavefroms it is capable of producing.

EXPERIMENT No. 27

SUBJECT

The thyratron saw-tooth generator.

OBJECTIVE

To test a typical thyratron saw-tooth generator; to observe the waveforms produced; to determine which circuit constants affect the output frequency and amplitude; to study a method of synchronizing the saw-tooth output to a desired frequency; and to observe the effect of using a non-sinusoidal saw-tooth waveform as a sweep voltage.

MATERIAL REQUIRED

1. Thyratron Saw-tooth Generator Chassis.
2. Five-inch oscilloscope with leads.
3. Power Supply Chassis.
4. Laboratory Chassis Mounting Rack.
5. Cathode Follower Chassis.
6. A-F oscillator with leads.
7. Vacuum-tube voltmeter with leads.
8. Bias Supply Chassis.

INSTRUCTIONS

A thyratron (gas triode or tetrode) tube is capable of producing a saw-tooth waveform by an action which is exactly the same as that of a neon tube. However, unlike the neon tube, the thyratron has a control grid; its ionization potential can be controlled over a considerable range—something that is impossible with the neon tube. Because of this flexibility, thyratrons are widely used in the sweep circuits of oscilloscopes and in some radar circuits.

The thyratron saw-tooth generator to be considered during this EXPERIMENT is a free-running device; that is, it does not require trigger pulses to make it operate. In this respect, it differs from the Saw-tooth Generator Chassis, which was considered earlier in the course, and is to be studied in EXPERIMENT No. 29. The Saw-tooth Generator Chassis uses a high-vacuum tube, and must be triggered by a negative pulse at the beginning of each cycle.

PROCEDURE

Familiarization

1. Obtain the items listed under MATERIAL REQUIRED.

2. Plug in the thyratron chassis, the bias chassis and the power supply chassis, leaving one space at the left.

3. Connect a voltmeter between ground and the INPUT jack of the Thyratron Saw-tooth Generator Chassis. Adjust the bias potentiometer for a negative bias of 1 volt on the thyratron control grid (SS-1 ALT. in bias chassis).

4. Connect the vertical scope lead to the OUTPUT jack. Observe that a saw-tooth waveform appears on the screen. Adjust the scope to display three cycles of this waveform.

5. Vary the bias potentiometer over its entire range. Note that this produces three effects; record these in the spaces provided below:

a. The frequency of the output waveform changes, becoming lower (higher or lower) when the grid bias is made more negative.

b. The linearity (straightness of that portion of the saw-tooth which rises slowly from left to right) becomes worse (better or worse) when the grid bias is made more negative.

c. The peak amplitude of the waveform becomes greater (greater or smaller) when the grid bias is made more negative.

Factors Affecting Frequency-and Amplitude

Grid Bias

1. Set R3 on the thyratron chassis at mid range.

2. Adjust the grid bias to -1 volt.

3. Measure the pulse repetition frequency and the peak amplitude of the waveform produced by this adjustment. Record them in A of TABLE 1.

4. Repeat the measurements, using successive grid biases of -1.5 and -2 volts. Record the results in A of TABLE 1.

Charging Capacitor C1.

1. Change C1 to .01.

2. Measure the pulse repetition frequency and the peak amplitude of the output waveform. Record them in B of TABLE 1.

3. Repeat the measurements, using a C1 value of .22 µf. Record the results in B of TABLE 1.

Charging Resistor R2

1. Return the .1 µf. capacitor to C1 and adjust the scope for 3 cycles.

2. Measure the pulse repetition frequency and the peak amplitude of the output waveform. Record them in C of TABLE 1.

3. Repeat the measurements, using a 100K resistor at R2. Record the results in C of TABLE 1.

Linearity

1. Adjust the thyratron saw-tooth generator to produce a *linear* saw-tooth waveform. Do this by inserting a .1-μf. capacitor at C1, placing a 47K resistor at R2, and adjusting potentiometer R3 in the bias supply until a negative bias of −1.0 volt appears at the thyratron control grid. Adjust the scope to present three cycles of this waveform. Trace the middle cycle accurately at A in figure 1.

2. Adjust the thyratron circuit to produce a *non-linear* saw-tooth waveform. Do this by inserting a .01-μf. capacitor at C1, and leaving the bias at −1.0 volt, the 22-μf. capacitor at C2, and the 47K resistor at R2. Adjust the scope to present three cycles of this waveform. Trace the middle cycle accurately at B in figure 1.

Use of Saw-tooth Waveform as Sweep Voltage

1. Replace capacitor C1 with the original value of 0.1 μf. Remove the connection between the output of the thyratron saw-tooth generator and the vertical input terminal of the scope. Connect thyratron generator output to the *horizontal* input terminal of the scope. Finally, turn the horizontal amplifier switch on the scope panel to the external position.

Inspection of the circuit will show that the saw-tooth voltage generated within the scope, and normally used as a sweep voltage on the horizontal scope plates, has been disconnected by the switch. In its place, we have impressed upon the horizontal plates the saw-tooth voltage produced by the Thyratron Saw-tooth Generator Chassis. The resulting pattern should be a straight horizontal line, identical in appearance with that obtained using the normal (internal) sweep.

2. Connect the output of the a-f oscillator to the vertical input terminal of the scope. Adjust the frequency of the a-f oscillator until a series of sine waves appears on the scope screen.

The scope is now making a normal presentation; the combination of a sine-wave vertical voltage and a saw-tooth horizontal voltage is producing sinusoidal traces upon the screen. Observe, however, that it is difficult to obtain a stationary trace. Manipulation of the sync control of the scope has no effect upon the trace. The reason for this condition is that, although sync voltage is applied to the grid of the sweep generator in the scope, the sweep generator has disabled by turning off the internal sweep.

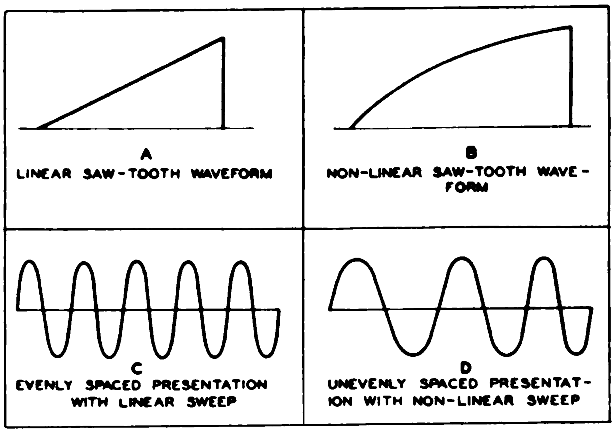
3. Insert the cathode follower next to the thyratron chassis, on the left and connect the INPUT jack of the cathode follower to the output terminal of the a-f oscillator. Adjust the a-f oscillator to produce an output voltage of approximately 2 volts.

This connection impresses a synchronizing voltage upon the control grid of the thyratron saw-tooth generator tube. The cathode follower is used merely as an isolation circuit between the a-f oscillator and the thyratron circuit. No matter what frequency is impressed upon the vertical plates of the scope, the same voltage appears upon the thyratron grid. The thyratron saw-tooth generator then produces a horizontal sweep voltage of the proper frequency to maintain a stationary trace upon the scope screen. Verify this statement by tuning the a-f oscillator over a range from 400 cycles to 3000 cycles. Describe the resulting patterns.

The sine waves are always synchronized but different numbers of sine-wave cycles appear because at high audio frequencies, the thyratron saw-tooth generator does not fire on every cycle of the a-f oscillator. The picture is always stationary. The picture stays locked in as frequency is varied.

Effect of a Non-linear Saw-tooth Sweep

1. Using the circuit just set up, adjust the thyratron saw-tooth generator to produce a *linear* sweep. The adjustments are those listed under step 1 of Linearity, and the waveform produced will be the one already traced at A in figure 1.



A LINEAR SAW-TOOTH WAVEFORM

B NON-LINEAR SAW-TOOTH WAVEFORM

C EVENLY SPACED PRESENTATION WITH LINEAR SWEEP

D UNEVENLY SPACED PRESENTATION WITH NON-LINEAR SWEEP

Figure 1. Waveforms Occurring in a Thyratron Saw-tooth Generator

2. Adjust the frequency of the a-f oscillator until 5 cycles of its sine-wave output appear on the scope screen. Plot this pattern to scale at C in figure 1. Note that the sine waves are spaced evenly across the screen.

3. Adjust the thyratron saw-tooth generator to produce a *non-linear* saw-tooth waveform. This adjustment is described in step 2 under Linearity, and the waveform produced will be the one sketched at B in figure 1.

4. Adjust the frequency of the a-f oscillator until 5 cycles of its sine-wave output appear on the scope screen. Plot this pattern accurately at D in figure 1. Note that the sine waves are crowded together at the right-hand side of the screen.

CONCLUSIONS

1. The thyratron grid voltage is used to (supply the necessary information):

a. Control the ionization voltage of the tube, thus controlling its operating condition.

b. Synchronize the saw-tooth generator (triggered).

2. The output frequency of the thyratron saw-tooth generator can be increased by:

a. Decreasing (increasing or decreasing) the negative bias.

b. Decreasing (increasing or decreasing) the value of C1.

c. Decreasing (increasing or decreasing) the value of R2.

3. The output voltage of the thyratron saw-tooth generator can be increased by:

a. True. Increasing the negative bias. (True or false.)

b. False. Decreasing the value of C1. (True or false.)

c. False. Decreasing the value of R2. (True or false.)

4. The linearity of the saw-tooth waveform produced by a thyratron saw-tooth generator can be improved by:

a.__________(increasing or decreasing) the negative bias.

b.__________(increasing or decreasing) the value of C1.

c.__________(increasing or decreasing) the value of R2.

5. Why is a linear sweep desirable when viewing waveforms on an oscilloscope screen?

An evenly spaced presentation of the voltage waves applied to the vertical-deflection plates is necessary for proper interpretation of any observed waveform. This means that the electron beam must move across the face of the scope at a linear rate.

6. Why is it desirable to reduce "flyback time" as much as possible?

To eliminate the objectionable return trace, and to give a usable sweep as nearly 100% of the time as possible.

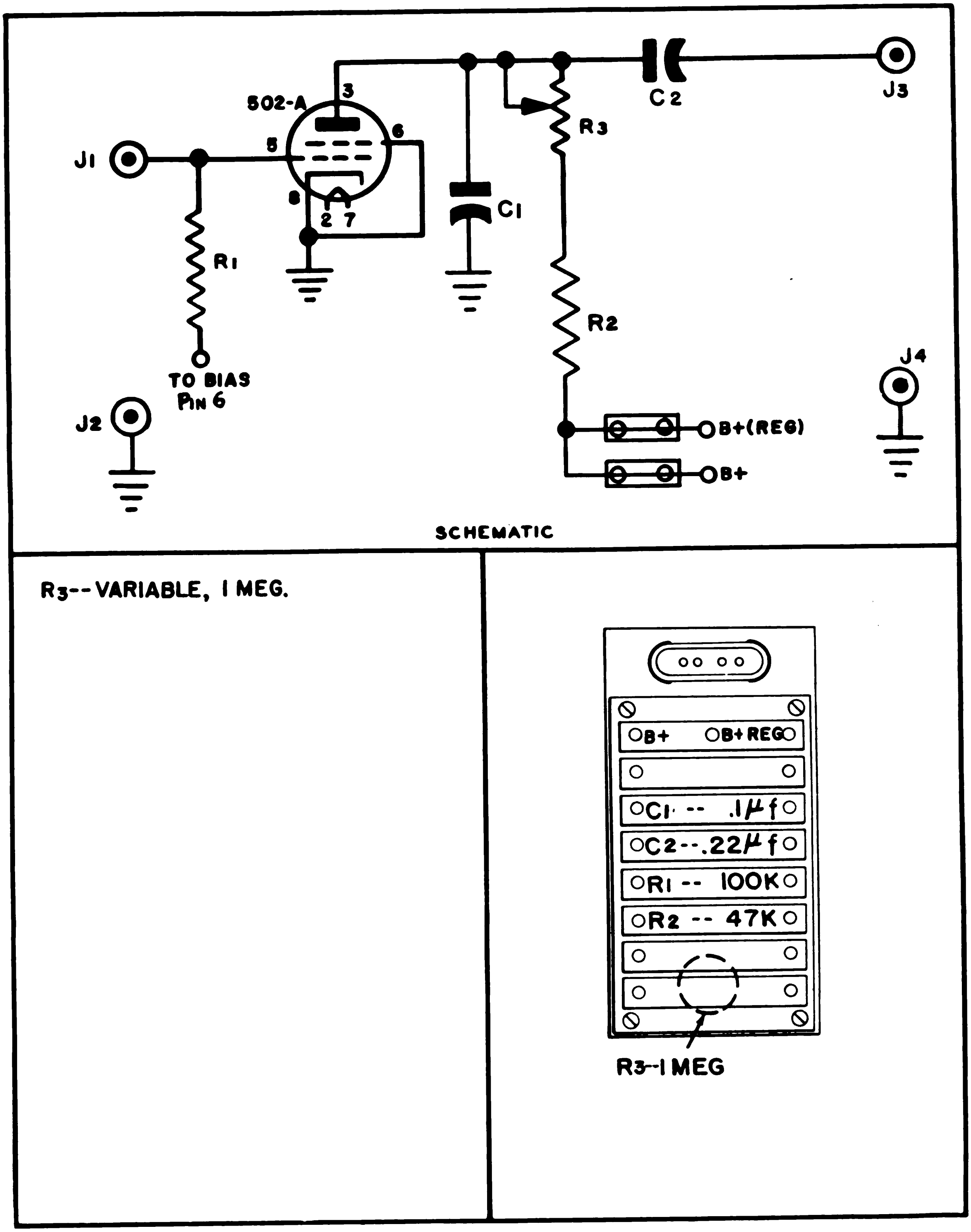
7. Why is the center cycle of a series of three cycles used when analyzing a waveform appearing on a scope screen?

The center cycle is used because it is usually most free of distortion. No flyback trace confuses the center cycle, but the first and third cycles are distorted at the ends.

TABLE 1

EFFECTS OF VALUES OF GRID BIAS, C3, AND R4 ON FREQUENCY AND AMPLITUDE

A. GRID BIAS		
Bias	Frequency (c.p.s.)	Amplitude (peak volts)
B. VALUE OF C1		
C1	Frequency (c.p.s.)	Amplitude (peak volts)
C. VALUE OF R2		
R2	Frequency (c.p.s.)	Amplitude (peak volts)



R3--VARIABLE, 1 MEG.

Schematic Diagram of Thyratron Saw-tooth Generator Chassis

LABORATORY PLAN No. 28

SUBJECT

The neon bulb saw-tooth generator.

OBJECTIVE

To familiarize the student with the operation of the neon bulb saw-tooth generator and the characteristics of the neon bulb.

MATERIAL REQUIRED

1. Neon Bulb Saw-tooth Generator Demonstration Unit.
2. Power Supply Demonstration Unit.
3. Vacuum-tube voltmeter with leads.
4. Five-inch oscilloscope with leads.
5. A-F oscillator with leads.
6. Neon Bulb, type NE32.
7. Set of plug-in parts as follows:
    - Resistor, 1000 ohms.
    - Resistor, 470,000 ohms.
    - Resistor, 2.2 megohms.
    - Capacitor, .01-μf.
    - Capacitor, .001 μf.
8. Bias Supply Chassis.

INTRODUCTION

This EXPERIMENT is to be given in the form of a laboratory demonstration. The student is to record the data obtained in his EXPERIMENT sheet along with circuit schematics and explanations.

The neon bulb is essentially an electronic switch. This demonstration is to clarify and illustrate the meaning of ionization and deionization potentials, and the use of the neon bulb as a switch. The effect of the bulb and other circuit components on frequency and linearity will also be discussed.

SUBJECT MATERIAL

1. Draw a diagram of the saw-tooth generator circuit, including all labels and values. (Refer to the EXPERIMENT.)

2. Explain the operation of the neon glow tube. The students must make notes on this subject, and must copy the circuit diagram.

3. Explain the operation of the circuit so that the students may take notes.

4. Using the Bias Supply Chassis and vacuum-tube voltmeter, measure the ionization and deionization potentials of the NE32 type of neon bulb. Have the students record the results in TABLE 1 of their EXPERIMENT.

5. Measure the frequency of the saw-tooth generator with the resistance-capacitance combinations in TABLE 2 of the EXPERIMENT. Have the students record the results.

6. Draw on the blackboard a graphical development of the output waveform for various values of R and C. (Refer to the EXPERIMENT.)

7. Draw on the blackboard a graphical development of the output waveform for various supply voltages. The students should record both graphs. (Refer to the EXPERIMENT.)

8. Use the output of the saw-tooth generator as an oscilloscope sweep voltage. Put in appropriate components to produce both a linear and a non-linear sweep. Put sine waves on the vertical-deflection plates, and illustrate the effect of a non-linear sweep. Have the students record their observations.

CONCLUSIONS

The neon bulb saw-tooth generator is perhaps the simplest form of saw-tooth generator. It is useful as a simple illustration of the saw-tooth relaxation oscillator.

EXPERIMENT No. 28

SUBJECT

The neon bulb saw-tooth generator.

OBJECTIVE

To become familiar with the operation of the neon bulb saw-tooth generator, and the characteristics of the neon bulb.

MATERIAL REQUIRED

1. Neon Bulb Saw-tooth Generator Demonstration Unit.
2. Power Supply Demonstration Unit.
3. Vacuum-tube voltmeter with leads.
4. Five-inch oscilloscope with leads.
5. A-F oscillator with leads.
6. Neon bulb, type NE32.
7. Set of plug-in parts as follows:
    - Resistor, 1000 ohms.
    - Resistor, 470,000 ohms.
    - Resistor, 2.2 megohms.
    - Capacitor, .01 µf.
    - Capacitor, .001 µf.
8. Bias Supply Chassis.

INSTRUCTIONS

This EXPERIMENT will be in the form of a laboratory demonstration, performed by the instructor. The voltage measurements, graphs, and waveforms developed during this demonstration are to be recorded in this EXPERIMENT. It will be the responsibility of the student to have a complete set of notes on the diagrams, waveforms, and explanations given by the instructor.

It will be shown that the neon bulb (glow tube) is essentially an electronic switch.

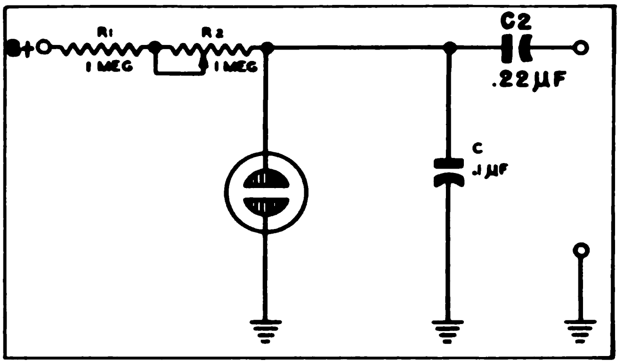
A study will be made of the d-c voltage levels required for ionization and deionization of the neon bulb, and of the frequency variations resulting from a change in circuit constants.

PROCEDURE

Circuit Diagram

1. Copy the diagram of the neon bulb saw-tooth generator circuit which the instructor will draw on the blackboard. Include all labels and values.

2. Make a set of notes on the instructor's preliminary explanation of the neon glow tube.



Schematic Diagram of Neon Saw-tooth Generator Chassis

The neon glow tube is a gas tube with two electrodes, which may be identical in physical structure. When voltage is applied, the free electrons in the low density gas of the tube become accelerated toward the anode (positive electrode). These electrons, moving at high velocities, strike the gas molecules, ejecting electrons from them. These ionized molecules move to the cathode. The ejected electrons produce still more free electrons by collision, and eventually strike the anode. This process continues until an equilibrium point is reached between the electrons produced and those recaptured. There is a minimum potential necessary for the tube to conduct. This potential is reached when the electrons are sufficiently accelerated to ionize the gas molecules. Once the tube has fired, even though the potential is lowered, the tube continues to conduct, because of the great number of electrons available to produce ionization. However, there is a minimum potential which will maintain the tube in conduction. This is the deionization potential.

3. Make a set of notes on the instructor's preliminary explanation of the circuit operation.

The capacitor charges exponentially through the resistor at a rate determined by the RC constant of the circuit, until the ionization potential of the tube is reached. The neon tube then fires, rapidly discharging the capacitor until the deionization potential is reached. The tube stops conducting, and the capacitor again charges.

Ionization and Deionization Measurements

1. In TABLE 1, for voltage measurements, record the values of d-c voltage required to ionize the NE32 type of neon bulb.

2. Record in the table the deionizing potential of NE32 neon bulb.

TABLE 1
VOLTAGE MEASUREMENTS

NOTE: Potentiometer R2 set for minimum resistance. R1 = 1000 ohms. Voltage source, bias supply with variable voltage output.

NEON BULB TYPE	D-C IONIZATION POTENTIAL (Volts)	D-C DEIONIZATION POTENTIAL (Volts)
NE32		

TABLE 2
FREQUENCY MEASUREMENTS

NOTE: Potentiometer R2 set for minimum resistance. Supply voltage, 105 volts.

NEON BULB NE32			
Resistor R1	Capacitor C1	Output Frequency (cycles/sec.)	Waveform Observed
1 meg	.1 μf.		
470 K	.1 μf.		
1000 ohms	.1 μf.		
470 K	.01 μf.		

Frequency Measurements

1. The instructor will measure the frequency of the saw-tooth generator with various resistors and capacitors in the circuit. Record these measurements in TABLE 2.

2. In view of these measured frequencies, what is the relationship of the time constant (RC) to the output frequency?

The frequency varies inversely with the RC time constant.

3. Calculate the output frequency of the saw-tooth generator under the following conditions: Neon bulb, NE32; resistor, 1.2 megohms; capacitor, .1 μf.; supply voltage, 200 volts. Use the formula:

$$f = \frac{1}{RC \times 2.3 \times \mathrm{Log}_{10} \frac{(E_{bb} - E_d)}{(E_{bb} - E_i)}}$$

$R1 = 1.2$ megohms
$C1 = .1 \mu f.$
$E_{bb} = 200$ volts
$E_d = 54$ volts
$E_i = 65$ volts

When f = frequency of the output saw-tooth, in cycles
R = charging resistance, in megohms
C = charging capacitance, in μf.
E_{bb} = supply voltage, in volts
E_d = deionization potential, in volts
E_i = ionization potential, in volts

Show all your work.

$$f = \frac{1}{1.2 \times .1 \times 2.3 = \mathrm{Log}_{10} \frac{(200-54)}{(200-65)}}$$

$$= \frac{1}{.12 \times 2.3 \times .034}$$

= 106 cycles

4. Determine the time constant (RC) for a frequency of 200 cycles, with neon bulb NE32 and a supply voltage of 200 volts. Use the same formula. Show all your work.

$$RC = \frac{1}{f \times 2.3 \times \mathrm{Log}_{10} \frac{(E_{bb} - E_d)}{(E_{bb} - E_i)}}$$

$$= \frac{1}{200 \times 2.3 \times .034}$$

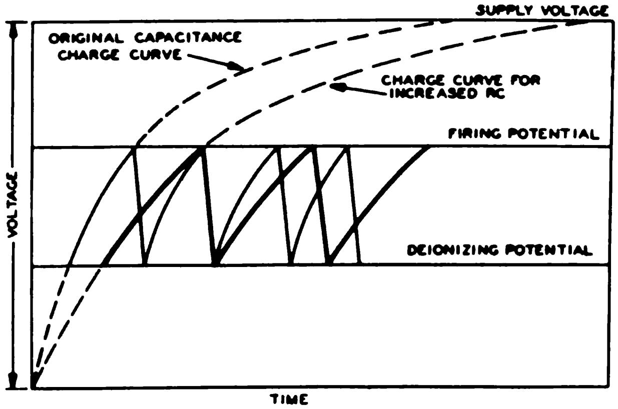
= .064 μsec.

5. Explain briefly what effect a higher supply voltage would have upon the output frequency.

A higher supply voltage increases the frequency, because the capacitor requires less time to charge from the deionizing potential to the ionizing potential.

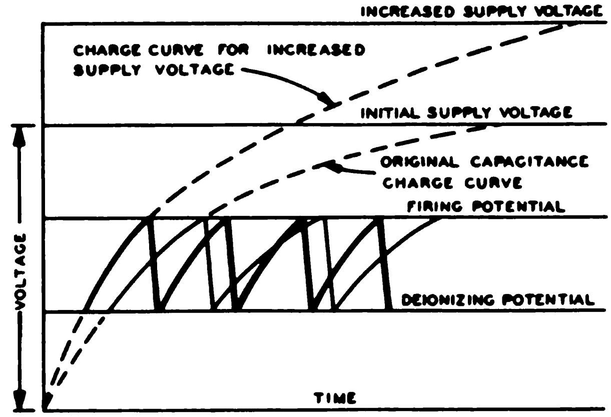
Graphs

1. Copy the output waveform for various values of R and C, which the instructor will draw on the blackboard.



Output Waveforms, Showing Effect of Changing RC Constant

2. Copy the output waveform for various supply voltages, which the instructor will draw on the blackboard.



Output Waveforms, Showing Effect of Changing Supply Voltage

Linearity

1. The instructor will employ the saw-tooth output of the neon bulb saw-tooth generator for the horizontal sweep on an oscilloscope. Record your observations.

2. Explain briefly the reason for the difference in linearity observed with the different adjustments made in step 1, above.

CONCLUSIONS

1. Explain, in not less than fifty words, how the saw-tooth waveform is developed in the neon bulb saw-tooth generator.

In this circuit, the neon bulb acts as an electronic switch; when it is not conducting, its impedance is infinite; when it is conducting, its impedance is very low. The capacitor charges through a resistor until the ionizing potential is reached. When the tube fires, it shorts the capacitor, discharging it rapidly. An exponential rise in voltage occurs across the capacitor (almost linear, if taken over a small portion of the charge curve), followed by an almost vertical drop.

2. Explain briefly the factors affecting frequency, ionization, deionization, and linearity.

The frequency is determined by the RC time constant which controls the rate of charge, the ionization and deionization potentials of the tube, and the supply voltage. The ionization and deionization potentials are determined by the characteristics of the tube. Linearity is determined by the RC time constant and the voltage of the power supply.

LABORATORY PLAN No. 29

SUBJECT

The vacuum-tube saw-tooth generator.

OBJECTIVE

To demonstrate to the students the effects of the charging time constant upon amplitude and linearity in a gated vacuum-tube saw-tooth generator; to have them compare the various degrees of linearity produced, and to observe the effects when the waveforms are used as a horizontal sweep voltage; to observe the effects of gate width upon amplitude and linearity.

MATERIAL REQUIRED

1. Square-wave Generator Chassis.
2. Saw-tooth Generator Chassis.
3. Single-Swing Blocking Oscillator Chassis.
4. One-Shot Multivibrator Chassis.
5. Five-inch oscilloscope, with cross-section screen and leads.
6. Vacuum-tube voltmeter with leads.
7. A-F oscillator with leads.
8. Power Supply Chassis.

INTRODUCTION

The vacuum-tube saw-tooth generator is well suited for a study of the linearity and amplitude of a saw-tooth wave, and the factors affecting them. The generator will not operate without an external pulse, and therefore, the frequency of the saw-tooth waveform is unaffected by changes in charging time.

SUBJECT MATERIAL

1. Supervise the connection of the equipment by the students.

2. Give a demonstration of the section in the EXPERIMENT concerning Effect of Charging Time Constant upon Saw-tooth Amplitude. Follow the steps given in the EXPERIMENT.

3. Give another demonstration on the section concerning Effect of Charging Time Constant upon Saw-tooth Linearity.

4. Supervise the section of the EXPERIMENT on Effect of the Charging Capacitor Value upon Saw-tooth Linearity.

5. Approve the students' results in the section on Effect of Gate Width, and initial their notebooks.

CONCLUSIONS

An understanding of the functioning of this circuit is essential in analyzing other circuits that are more complex in nature, which will be studied later. It was shown that, regardless of the RC combination in the circuit itself, the frequency of the saw-tooth waveform generated was dependent solely upon the frequency of the input signal. Other circuits do not exhibit this characteristic; therefore, the effects of circuit components on linearity and amplitude are more difficult to observe in other circuits.

EXPERIMENT No. 29

SUBJECT

The vacuum-tube saw-tooth generator.

OBJECTIVE

To study the effects of the charging time constant upon amplitude and linearity in a gated vacuum-tube saw-tooth generator; to compare the various degrees of linearity produced, and to observe the effects when the waveforms are used as a horizontal sweep voltage; to observe the effects of gate width upon amplitude and linearity.

MATERIAL REQUIRED

1. Square-wave Generator Chassis.
2. Saw-tooth Generator Chassis.
3. Single-Swing Blocking Oscillator Chassis.
4. One-Shot Multivibrator Chassis.
5. Five-inch oscilloscope, with cross-section screen and leads.
6. Vacuum-tube voltmeter with leads.
7. A-F oscillator with leads.
8. Power Supply Chassis.

INSTRUCTIONS

The Saw-tooth Generator Chassis, tested earlier in the course, has been used frequently as a source of saw-tooth waveforms. The student has now advanced to a point where he is equipped to understand the circuit operation of this chassis. It will, accordingly, be studied at this time.

The chassis employs a vacuum-tube saw-tooth generator circuit which, unlike the thyratron saw-tooth generator, is not free-running. The vacuum-tube circuit will produce a saw-tooth waveform only during the time when its grid is blocked by a negative "gate" pulse. At all other times, there will be no output from the generator. Therefore, the output frequency of the chassis is totally dependent upon the frequency of the input gate pulse, and is unaffected by any changes in the charging time constant, the supply voltage, or any other circuit constant. This characteristic makes the vacuum-tube saw-tooth generator an ideal circuit with which to make a laboratory study of the effects of gate-pulse width, charging resistance, and charging capacitance upon saw-tooth waveform amplitude and linearity. Such a study will be made during this EXPERIMENT.

PROCEDURE

Connection of Equipment

1. Insert the square-wave generator and the saw-tooth generator in the same row of the rack but leave one space between them. Insert the power supply in the same row.

2. The frequency of the square-wave generator is approximately 200 cycles.

3. Adjust the scope to present three cycles of the saw-tooth waveform occurring at the OUTPUT jack of the saw-tooth generator.

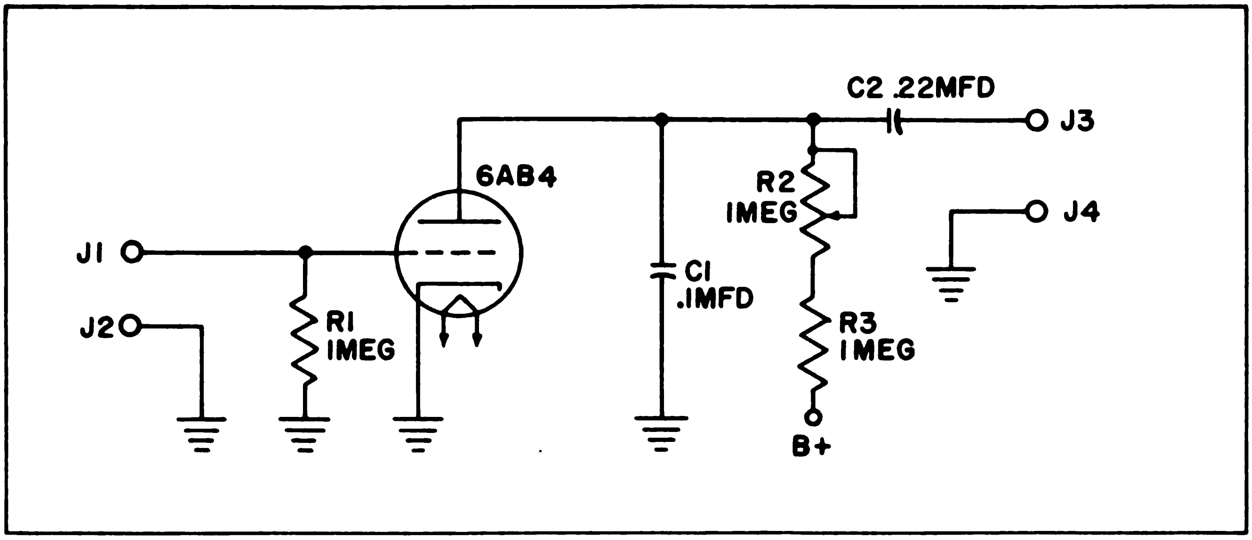


Figure 1. Saw-tooth Generator Circuit

Effect of Charging Time Constant Upon Saw-tooth Amplitude

1. Vary the charging-resistor potentiometer, R2, of the saw-tooth generator over its entire range. Note that increasing the resistance of R2 lowers the amplitude of the saw-tooth waveform.

2. Set R2 at its minimum-resistance reading, so that the only charging resistance left in the circuit is R3. Measure the amplitude of the output waveform. Then remove the trigger pulses by disconnecting the lead between the square-wave generator and the saw-tooth generator. Measure the d-c voltage between the saw-tooth generator plate and ground.

This is the minimum voltage to which the charging capacitor, C1, will discharge; such a figure will be used later in the EXPERIMENT in predicting the waveform that will be obtained under certain specified conditions.

Saw-tooth amplitude (charging resistance = 1 megohm), _____ volts.

Minimum d-c plate voltage under these conditions, _____ volts.

3. Shut off the power and adjust R2 until the total charging resistance in the circuit is 1.5 megohms. Turn on the power, adjust the scope to display three cycles of the saw-tooth waveform, and measure the saw-tooth amplitude and the minimum d-c plate voltage, as was done in the preceding step.

Saw-tooth amplitude (charging resistance = 1.5 megohms), _____ volts.

Minimum d-c plate voltage under these conditions, _____ volts.

4. Adjust R2 until the total charging resistance in the circuit is 2 megohms, and adjust the scope to display three cycles of the saw-tooth waveform. Measure the saw-tooth amplitude and the minimum d-c plate voltage.

Saw-tooth amplitude (charging resistance = 2 megohms), _____ volts.

Minimum d-c plate voltage under these conditions, _____ volts.

Effect of Charging Time Constant Upon Saw-tooth Linearity

1. Leave the charging resistance set at 2 megohms, as in the preceding step. Observe the saw-tooth waveform produced, and record one cycle accurately at A in figure 2. Enter on the sketch the minimum d-c voltage and the maximum voltage (minimum d-c voltage plus saw-tooth amplitude).

2. Turn the power off. Turn R2 on the saw-tooth generator fully clockwise and insert a 22K resistor for R3. CAUTION: Do not turn R2 during this portion of the EXPERIMENT. Turn the power on and draw the resulting waveform at B in figure 2. Enter on this sketch the maximum and minimum voltages reached by the charging capacitor.

3. Repeat step 2, using a total charging resistance of 10,000 ohms. Draw the resulting waveform at C in figure 2. Enter the maximum and minimum voltages involved. Observe the caution given above.

A. Linear Waveform obtained with a time constant of 200,000 μsec. (.1 μf. and 2 megohms) and a period of 5000 μsec.	
B. Slightly non-linear waveform obtained with a time constant of 2200 μsec. (.1 μf. and 22,000 ohms) and a period of 5000 μsec.	
C. Non-linear waveform observed with a time constant of 1000 μsec. (.1 μf. and 10,000 ohms) and a period of 5000 μsec.	

Figure 2. Effect of Charging Time Constant upon Linearity of a Saw-tooth Waveform

Effect of Charging Capacitor Value Upon Saw-tooth Linearity

1. Adjust the total charging resistance to 1 megohm.

2. Remove the .1-μf. charging capacitor, C1, and insert a .22-μf. capacitor.

These changes produce a charging time constant of 220,000 μsec., which is nearly the same as the time constant produced earlier in the EXPERIMENT by the use of a 2 megohm resistance and a .1-μf. capacitance. The student will now determine whether the value of C1 has any effect upon the saw-tooth amplitude and linearity, as long as the time constant remains unchanged.

Figure 3. Waveform Obtained When Charging Capacitor Is Changed Without Changing Time Constant. (Compare with A in figure 2.)

3. Adjust the scope to display three cycles of the saw-tooth waveform.

4. At figure 3, draw one cycle of the resulting waveform. Measure and record the maximum and minimum voltages across the charging capacitor.

5. Compare this waveform with the trace recorded at A in figure 2. Discuss and explain their relative shapes and sizes.

Effect of Gate Width

1. Connect the equipment as shown in the block diagram of figure 4. The gate must have a pulse repetition frequency of 250 p.p.s.

2. Adjust the scope to display three cycles of the waveform occurring at the OUTPUT jack of the saw-tooth generator.

3. Note the effects upon the waveform of varying the width of the gate and the resistance of the charging resistor, R2, of the saw-tooth generator. Manipulate these controls until you are thoroughly familiar with the results produced. Note that the saw-tooth voltage rises *only while the gate is open* (while a negative voltage is applied to the grid of the saw-tooth generator tube); the narrower the gate becomes, the more linear is the saw-tooth; the higher the charging resistance, the more linear the saw-tooth.

CONCLUSIONS

1. On a sheet of graph paper, plot the saw-tooth waveform that should be obtained from OUTPUT jack J3 of the saw-tooth generator under the following conditions:

Charging resistance (total), 250,000 ohms.
Charging capacitance, .02 μf.
Trigger-pulse width, 10,000 μsec.
B plus voltage, 360 volts.
Minimum charging-capacitor voltage, 30 volts.

(Use the chart on page 292 or the exponential-rise chart in TM 11-466.)

2. On the same sheet of graph paper, plot the saw-tooth waveform that should be obtained under the following conditions:

Charging resistance (total), 1.25 megohms.
Charging capacitance, .02 μf.
Trigger-pulse width, 10,000 μsec.
B plus voltage, 360 volts.
Minimum charging-capacitor voltage, 75 volts.

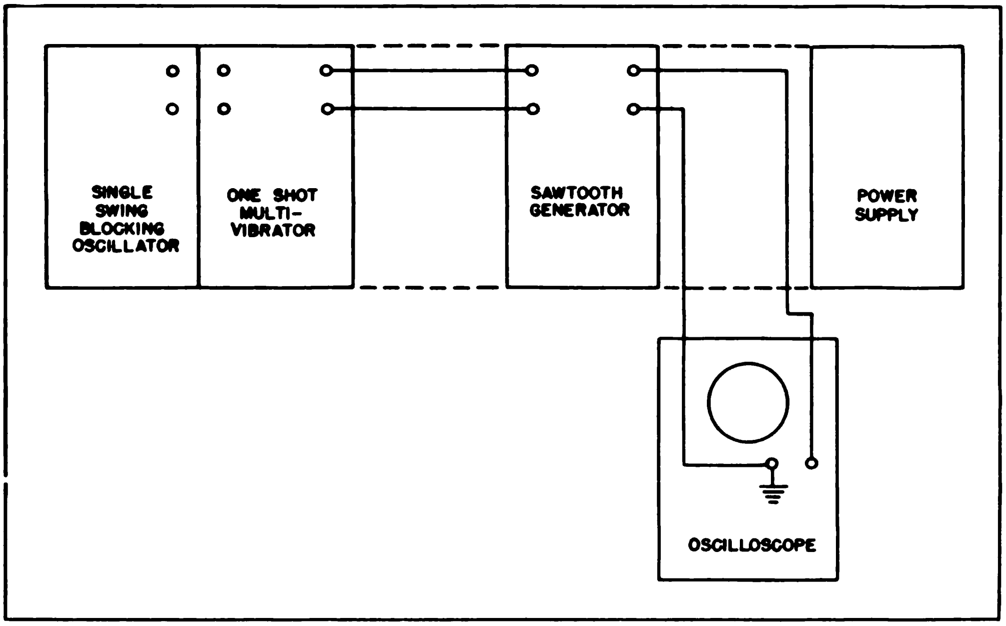


Figure 4. Block Diagram of Equipment Used for Observing Effects of Gating and Stepping

3. Compare the amplitude and linearity of the two traces plotted in 1 and 2, above. Explain *why* a change in the charging time constant affected the amplitude and the linearity. Develop a general rule to guide you later in the course, in changing parts in this circuit to obtain any desired combination of gate width, linearity, and amplitude.

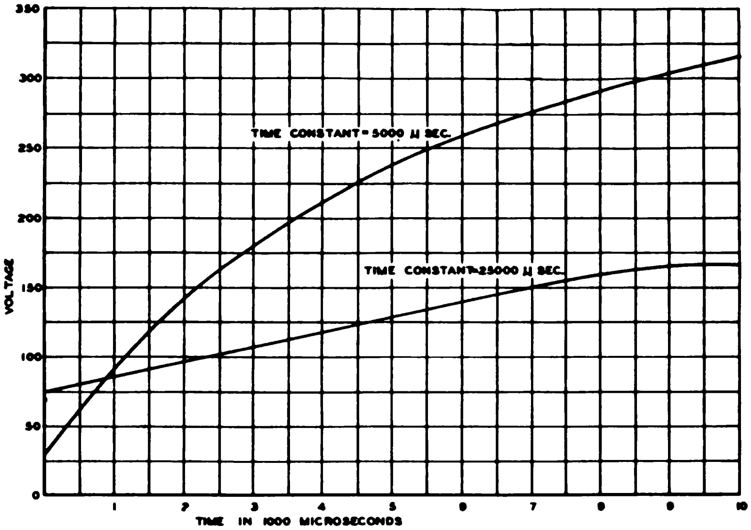
Curve 2 is more linear, but has a lower amplitude. The period is the same, but the time constants are different. In the same time curve 2 will not charge as far (lower amplitude); therefore, a smaller portion of its charge curve is covered (better linearity).

4. How does the function of R3 in this saw-tooth generator differ from that of R2 in the thyratron saw-tooth generator?

The function of R2 in the thyratron circuit is to limit the tube current and protect the tube. The function of R3 in the vacuum-tube circuit is to provide a jump-step.

5. What controls the frequency of the vacuum-tube saw-tooth generator?

The frequency of the triggering pulse.



Output Waveforms of the Saw-tooth Generator
Under Different Conditions

LABORATORY PLAN No. 30

SUBJECT

Analyzing and testing the voltage tripler.

OBJECTIVE

To supervise the testing of a voltage tripler, to be used as a voltage source in connection with the Cathode-Ray Oscilloscope Chassis.

MATERIAL REQUIRED

1. Voltage Tripler Chassis.
2. Vacuum-tube voltmeter with external .01-μf. capacitor connected in series with its ungrounded lead.
3. Five-inch oscilloscope with leads.
4. A-F oscillator with leads.
5. Power Supply Chassis.
6. Laboratory Chassis Mounting Rack.

INTRODUCTION

The equipment to be tested in this EXPERIMENT will be used as a high-voltage source for the cathode-ray oscilloscope to be tested in the following EXPERIMENT. Since the voltages developed in this circuit are moderately high, extreme care should be exercised during the testing of the circuit.

SUBJECT MATERIAL

1. Supervise the testing of the circuit, emphasizing that the directions given in the EXPERIMENT must be followed implicitly.

2. Instruct the student to fill out the table of operating voltages for future reference. Check these voltages for accuracy.

CONCLUSIONS

Voltage-multiplying circuits are used where it is inconvenient to use a transformer large enough to supply the high voltage required, or where it is desired to obtain sufficient plate voltage to properly operate small vacuum tubes from a 115-volt, a-c source without using a transformer. The voltage regulation in this type of circuit, however, is poor. Even though the process of cascading multiplier circuits may be carried on indefinitely, there are several limitations that must be observed which will reduce the practical total number of such circuits to only a few. Ordinarily, the process is not carried beyond voltage quadrupling.

EXPERIMENT No. 30

SUBJECT

Analyzing and testing a voltage tripler.

OBJECTIVE

To analyze and test a voltage tripler, to be used as a voltage source in connection with the Cathode-Ray Oscilloscope Chassis.

MATERIAL REQUIRED

1. Voltage Tripler Chassis.
2. Vacuum-tube voltmeter with external .01-μf. capacitor connected in series with its ungrounded lead.
3. Five-inch oscilloscope with leads.
4. A-F oscillator with leads.
5. Power Supply Chassis.
6. Laboratory Chassis Mounting Rack.

INSTRUCTIONS

The power supply to be tested during this EXPERIMENT will be used to furnish high voltage for the cathode-ray oscilloscope that is to be used in the next EXPERIMENT. The supply uses a step-up transformer and a selenium-rectifier voltage tripler to convert the 6.3-volt heater supply of the Laboratory Chassis Mounting Rack to 400 volts (approximately).

Special care is necessary in setting up and testing this chassis. Refer to the EXPERIMENT covering the testing of a selenium-rectifier bias supply, and observe all the precautions mentioned there. These precautions apply with even more force to the present chassis, since higher voltages are involved.

PROCEDURE

1. Remove C2 and C3 from the circuit. This leaves only C1, CR2, and the limiting resistor active.

2. Apply power to the circuit, and measure the d-c voltage developed across C1.

CAUTION

THE VOLTMETER SHOULD BE CONNECTED ACROSS C1 BEFORE POWER IS APPLIED, AND SHOULD BE WATCHED CAREFULLY AS THE SWITCH IS THROWN. IF VOLTAGE DOES NOT APPEAR INSTANTLY, TURN OFF THE POWER AND CHECK FOR THE SOURCE OF TROUBLE. REMEMBER THAT NO WARM-UP TIME IS REQUIRED WHEN WORKING WITH THIS CIRCUIT—THE SELENIUM RECTIFIERS OPERATE INSTANTANEOUSLY, AND THE RECTIFIER TUBE IN THE POWER-SUPPLY UNIT IS NOT A PART OF THE CIRCUIT, SO THERE IS NO CIRCUIT COMPONENT THAT REQUIRES TIME TO COME UP TO OPERATING TEMPERATURE. FAILURE TO DEVELOP VOLTAGE THE INSTANT THE SWITCH IS CLOSED INDICATES IMPROPER OPERATION.

3. If the voltage across C1 is approximately 110—165 volts, turn off the power. Watch the voltmeter, to observe whether the voltage falls off slowly, indicating that C1 is in good condition. If the voltage falls to zero as soon as the switch is opened, it means that C1 is leaky or has lost most of its capacitance. If so, further checks with an ohmmeter and a capacitor checker should be made.

4. If the results of step 3 are satisfactory, C1 and CR2, and R1, and the power transformer are operating properly.

5. Insert C2, and test for voltage across its terminals in the same manner described in connection with C1. The voltage across C2 should be approximately 220—330 volts, and should decrease slowly after the power switch has been opened. If these indications are obtained, C2 and CR1 are operating properly.

6. Insert C3, and test for voltage across its terminals in the same way. The voltage should be approximately 110—165 volts, and should also decrease slowly after the power switch has been opened. If these indications are obtained, C3 and CR3 are functioning, and the entire circuit should be free from trouble.

7. As a final check, measure the d-c voltage across the terminals of C1, C2, and C3, with all the parts in the chassis. These three voltages should be 110—165, 220—330, and 110—165 volts, respectively. The voltage across the OUTPUT jacks of the chassis should be 330—495 volts.

Typical Operating Voltages

1. Allow the voltage tripler to operate, without load, for 15 to 20 minutes. Check for overheating of parts. Selenium rectifiers require a certain amount of "aging" (operating under no-load conditions) before they reach their stable operating characteristics. During this aging period, abnormally heavy currents may flow, and special attention should be paid to limiting resistor R1, to make sure that it does not overheat. If overheating should occur, turn off the equipment until the resistor cools, then turn on the power again. If heating persists, call upon the instructor to check your equipment.

2. At the end of the 20 minute period, make the following measurements, and record them for future reference:

Voltage across C1 ____ volts, d.c.

Voltage across C2 ____ volts, d.c.

Voltage across C3 ____ volts, d.c.

Voltage across the two OUTPUT jacks ____ volts, d.c.

Voltage across R1 (with no load) ____ volts, d.c.

Current through R1 (calculated) ____ milliamperes

Voltage across secondary of transformer ____ volts, a.c.

A-C ripple voltage across OUTPUT jacks ____ volts, a.c.

Percentage of ripple (100×a.c./d.c.) ____ percent

Ripple frequency ____ cycles

3. Obtain the instructor's approval of these readings.

Instructor's initials____

CONCLUSIONS

1. What might cause R1 to overheat after the aging period has been completed?

2. What might cause the voltage across C2 to be less than 100 volts?

3. How would you proceed in finding the cause of excessive ripple at the OUTPUT jacks?

Observe the waveforms across the capacitors individually. Replace the capacitor exhibiting ripple with one which is known to be good.

4. What is the most likely cause of overheating of C2? What would you do to correct the trouble, and what precautions would you take to guard against a recurrence of the overheating?

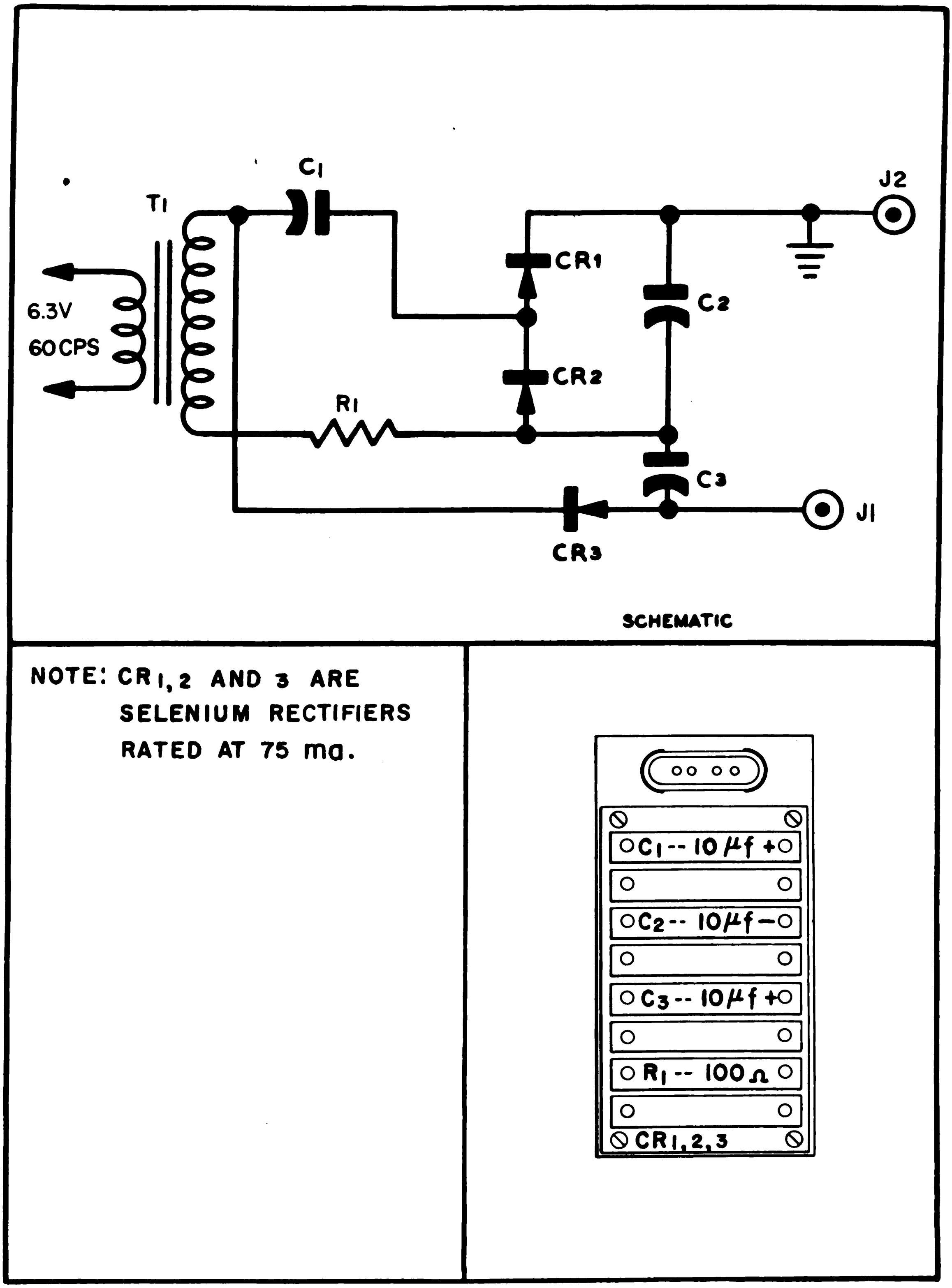
5. What advantages do you consider the selenium-rectifier voltage tripler to have over a similar device using vacuum tubes, and over a standard transformer-type power supply delivering the same voltage?

Advantages over vacuum tubes.

a. Compactness.
b. Long life.
c. Economy.
d. Cool operation.

Advantages over transformer.

a. Compactness.
b. Long life.
c. Economy.
d. Light weight.
e. Less tendency to set up magnetic fields and introduce hum into remote parts of the circuit.
f. Cool operation.



NOTE: CR1,2 AND 3 ARE
SELENIUM RECTIFIERS
RATED AT 75 ma.

Schematic Diagram of Voltage Tripler Chassis

LABORATORY PLAN No. 31

SUBJECT

Testing the basic oscilloscope.

OBJECTIVE

To make resistance and voltage checks on the basic oscilloscope; to compile tables of typical resistance and voltage readings for use in trouble-shooting this equipment; and to measure the deflection sensitivity of both the horizontal and the vertical plates.

MATERIAL REQUIRED

1. Cathode-Ray Oscilloscope Chassis.
2. Vacuum-tube voltmeter with leads.
3. Voltage Tripler Chassis.
4. Audio Signal Generator.
5. Laboratory Chassis Mounting Rack.
6. Power Supply Chassis.

INTRODUCTION

The Basic Oscilloscope Chassis will be thoroughly tested. Resistance and voltage measurements will be made. The accuracy of these measurements will affect the success of the next EXPERIMENT, which deals with trouble shooting the oscilloscope.

SUBJECT MATERIAL

Supervise the student in making resistance and voltage readings. Be sure these readings are accurate.

Have the student make all adjustments, as outlined in the EXPERIMENT. Be sure these adjustments are correct. Check the work frequently.

CONCLUSIONS

The student has now studied the basic oscilloscope and tested it. He should be familar with the voltage-divider circuits involved, and should be capable of going on to trouble-shoot the chassis in the following EXPERIMENT.

EXPERIMENT No. 31

SUBJECT

Testing the basic oscilloscope.

OBJECTIVE

To make resistance and voltage checks upon the basic oscilloscope; to compile tables of typical resistance and voltage readings for use in trouble shooting this equipment; and to measure the deflection sensitivity of both the horizontal and the vertical plates.

MATERIAL REQUIRED

1. Cathode-Ray Oscilloscope Chassis.
2. Vacuum-tube voltmeter with leads.
3. Voltage Tripler Chassis.
4. Audio Signal Generator.
5. Laboratory Chassis Mounting Rack.
6. Power Supply Chassis.

INSTRUCTIONS

The basic oscilloscope consists of a two-inch cathode-ray tube and a voltage-divider network that distributes all the fixed and variable voltages required by the tube. As in the case of any voltage-divider circuit, a change in current in one part of the network causes all voltages throughout the system to change. This interdependence can produce mystifying symptoms in circuits where no trouble exists, often distracting attention from a circuit that contains the real source of trouble.

To enable the student to proceed intelligently in trouble shooting the basic oscilloscope, most of this EXPERIMENT will be devoted to compiling tables of resistance and voltage measurements, made at a time when the equipment is operating properly. These tables will be useful in a later EXPERIMENT on trouble shooting this equipment. They will also lead to a familiarity with typical oscilloscope divider networks, and will prepare the student to work on other types of scopes.

Do not connect the Power Supply Chassis to the Cathode-Ray Oscilloscope Chassis until all specified resistance measurements have been made, and have been approved by the instructor. This will minimize the chance of damaging the equipment, because of improper connections.

PROCEDURE

Resistance-Measurements

(with cathode-ray tube socket removed)

1. Refer to TABLE 1. Make all the resistance measurements indicated, and record them in the proper spaces. Use the ohmmeter section of the vacuum-tube voltmeter.

2. Obtain the instructor's approval of your results before proceeding.

Instructor's initials_____

Voltage Measurements

1. Replace the tube socket and connect the Cathode-Ray Oscilloscope Chassis the power supply, and the Voltage Tripler Chassis. (Use a power plug extension cord to connect the oscilloscope to facilitate taking readings.

WARNING:

APPROXIMATELY 400 VOLTS IS PRESENT AT THE OUTPUT OF THE VOLTAGE TRIPLER.

2. With the voltmeter in the vertical jack, adjust R6 for 0 volts. With the voltmeter in the horizontal jack, adjust R7 for 0 volts. Turn up the intensity and the spot should appear on the scope. Adjust the focus control for a small spot.

3. Refer to TABLE 2. Measure all the voltages indicated, and record them in the proper spaces. Use the v.t.v.m.; a meter of lower resistance will give incorrect readings when connected across some of the high-resistance units of the voltage-divider network.

4. Obtain the instructor's approval of your results before proceeding.

Instructor's initials_____

Deflection Sensitivity

1. Adjust the scope controls until a faint green spot appears at the exact center of the screen. Keep the intensity of this spot low, so that it will not burn the scope screen.

Do not make further adjustments of the positioning controls until all measurements of deflection sensitivity have been completed.

2. Connect the equipment to make it possible to apply an audio voltage directly to either the horizontal or the vertical deflection plates.

3. Connect the audio signal generator to the ungrounded horizontal plate of the cathode-ray tube. Adjust the voltage to 2 volts at 60 cps (peak to peak). Measure and record the width of the trace. ____ inch

4. Disconnect the signal generator from the horizontal plate, and connect it to the vertical plate. Adjust the voltage to exactly 2 volts. Measure and record the height of the trace.

____ inch

Horizontal deflection sensitivity, in inches per volt, ____ inch per volt

Vertical deflection sensitivity, in inches per volt,

CONCLUSIONS

TABLE 1
RESISTANCES

OHMMETER CONNECTIONS	CONTROL POSITION	RESISTANCE READING
Pin 8 of power plug Ground	—	0
Pin 12 of power plug Ground	—	Infinity
Pin 8 of tube socket Ground	—	0
Pin 6 of tube socket Ground	—	0
Pin 9 of tube socket Ground	—	0
Pin 3 of tube socket Pin 2 of tube socket	R1 cw.	0
	R1 ccw.	12k
Pin 3 of tube socket Pin 4 of tube socket	R3 cw.	10k
	R3 ccw.	22k
Pin 3 of tube socket Pin 8 of tube socket	R3 cw.	90k
	R3 ccw.	90k
Pin 10 of tube socket Pin 7 of power plug	R1 cw.	1.2 meg
	R1 ccw.	1.15k
Pin 7 of power plug Pin jack Z (J2)	—	150k
	—	—
Pin 5 of power plug Pin 4 of tube socket	R3 cw.	220k
	R3 ccw.	380k
Pin 5 of power plug Junction R4, R5	—	56k
Ground (J1) Junction R4, R5	—	48k
Pin 7 of power plug Ground	—	150k
Pin 7 of power plug Junction R4, R5	—	100k
Pin jack V (J4) Ground	R6 cw.	1.25 meg
	R6 ccw.	1.2 meg
Pin jack H (J3) Ground	R7 cw.	1.5k
	R7 ccw.	1.2k
Pin jack H (J4) Pin jack V (J3)	R6, R7 both cw.	2.3 meg
Pin jack H (J4) Pin jack V (J3)	R6, R7 both ccw.	2.2 meg
Pin 5 of power plug Ground	—	110k
Pin 5 of power plug Pin 7 of power plug	—	160k

TABLE 2
VOLTAGES

VOLTMETER CONNECTIONS	CONTROL POSITION	VOLTAGE READING
Pin 5 of power plug Pin 7 of power plug		625v
Across R1		52v
Across R2		48v
Across R4		100v
Across R5		46v
Across R8		0.15v
Across R9		0.15v
Across R10		160v
Voltage at one end of R5		46v
Other end of R5		0v
Movable arm of R3 Jack Z	R3 cw.	45v
	R3 ccw.	100v

1. Using the data compiled in TABLE 2, enter the voltages in the schematic diagram.

Calculate the maximum current flowing in each resistor, and calculate the power each resistor is dissipating. Show all your work.

2. What is the purpose of resistors R8 and R9?

When R6 is in the clockwise position, there would be no resistance in the circuit from the horizontal deflection plates to ground if resistor R8 were removed. The same condition would exist if R9 were removed. Hence, these resistors are used to develop the signal voltages required on the horizontal and vertical deflection plates.

3. Explain briefly why the horizontal-deflection sensitivity differs slightly from the vertical-deflection sensitivity.

The vertical plates are farther from the screen than are the horizontal plates. A given voltage on the deflection plates will cause a specific angular displacement of the electron beam. The displacement of the spot on the screen equals the product of the distance from the screen to the plates and the tangent of the angle of displacement. Hence, vertical deflection sensitivity is greater in the case of the more distant vertical plates.

4. b . A spot appearing 1 inch below and one inch to the left of the center of the screen would indicate which of the following conditions?

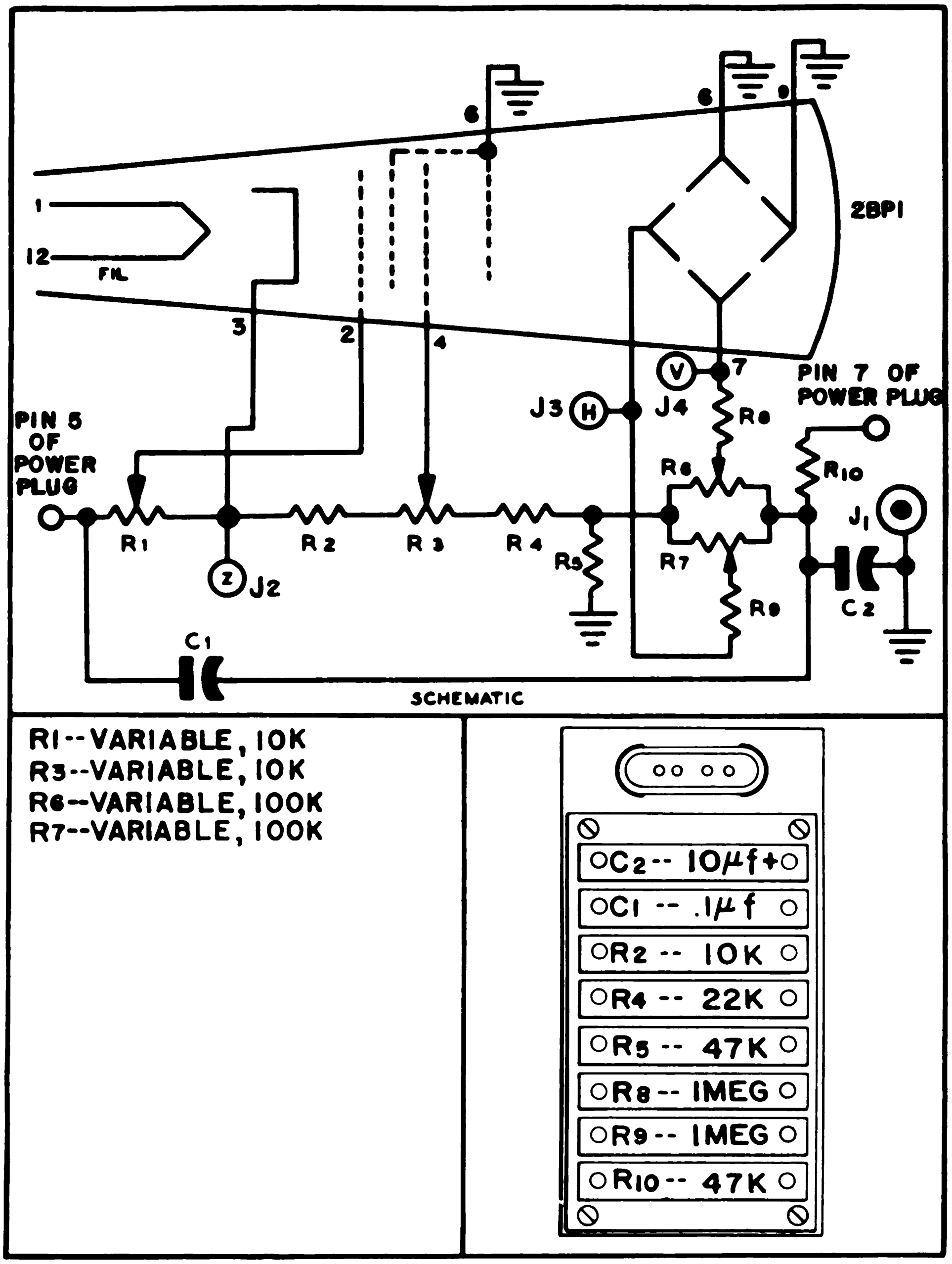
a. The two deflection voltages are equal in amplitude, but 180 degrees out of phase.

b. The voltages on the horizontal and vertical plates are of the same polarity and amplitude.

c. The voltage on the vertical plates is negative with respect to the voltage on the horizontal plates.

5. What is the purpose of capacitors C1 and C2?

C1 and C2 are filter capacitors; they maintain a constant dc voltage across the voltage divider.



Schematic Diagram of Cathode-Ray Oscilloscope Chassis

LABORATORY PLAN No. 32

SUBJECT

Trouble shooting the basic oscilloscope.

OBJECTIVE

To supervise the student in trouble shooting the basic oscilloscope.

MATERIAL REQUIRED

1. Cathode-Ray Oscilloscope Chassis.
2. Voltage Tripler Chassis.
3. Vacuum-tube voltmeter with leads.
4. A-F Oscillator with leads.
5. Power Supply Chassis.

INTRODUCTION

The cathode-ray oscilloscope is the most important single instrument used in servicing radar. The oscilloscope of this EXPERIMENT is typical of oscilloscope circuits, but is very much simplified. In servicing it, the student should observe the symptoms and decide which condition will produce them. He should compare measurements made on the circuit with those taken in the previous EXPERIMENT. Remind the students that any change in current through any of the voltage-divider resistors will cause all the voltages to change.

SUBJECT MATERIAL

1. Have the student operate the oscilloscope. Make certain that all scopes are in good working order. Check the equipment before the student continues.
2. Insert troubles into the equipment.
3. Be sure to check the student's procedure in locating the trouble. The work should be recorded on the JOB SHEET. Check it thoroughly.

CONCLUSIONS

The circuit of this oscilloscope is typical of other oscilloscope circuits. The student is basically interested in the voltage-divider network and the cathode-ray tube. These components are found in all oscilloscopes which are used extensively in testing radar equipment.

EXPERIMENT No. 32

SUBJECT

Trouble shooting the basic oscilloscope.

OBJECTIVE

To become familiar with methods of locating trouble in a typical oscilloscope circuit.

MATERIAL REQUIRED

1. Cathode-Ray Oscilloscope Chassis.
2. Voltage Tripler Chassis.
3. Vacuum-tube voltmeter with leads.
4. A-F Oscillator with leads.
5. Power Supply Chassis.

REFERENCES

Notes on previous trouble-shooting procedures studied during this course. TABLES 1 and 2, compiled during previous EXPERIMENT.

INSTRUCTIONS

The ability to trouble-shoot his test equipment is as important to the radar technician as the ability to maintain the radar gear itself. Familiarity with the characteristics and limitations of each piece of test equipment, and the ability to recognize symptoms of faulty operation in test equipment, will frequently save the technician the embarrassment of learning that he has wasted hours of time tracking down nonexistent trouble in a piece of radar equipment.

The most important single test instrument for radar work is the oscilloscope. The basic oscilloscope used in the previous EXPERIMENT is typical of most of the scopes in common use. It is, of course, simplified to the bare essentials. But familiarity with the indications produced by improper functioning of the voltage-divider network will give the student a solid foundation upon which to build a trouble-shooting procedure applicable to other scopes, no matter how elaborate they may be.

In trouble shooting the basic oscilloscope, first note and record the symptoms observed. Refer to the schematic diagram of the chassis, and decide which circuit condition could produce the symptoms observed. Then consult the tables of typical resistance and voltage measurements, compiled during the previous EXPERIMENT, and compare them with measurements made upon the chassis in its present inoperative condition. If abnormal resistances or voltages are found, track down the trouble, using standard trouble-shooting procedures learned earlier in the course. Do not overlook the fact that a change in current through any one of the voltage-divider resistors will cause all other voltages to change. In this case, resistance measurements are usually the most reliable guide to the source of the trouble.

PROCEDURE

1. Mount the Cathode-Ray Oscilloscope Chassis and Voltage Tripler Chassis in the Laboratory Chassis Mounting Rack. Connect them as in the previous EXPERIMENT and turn on the power.
2. Adjust the spot to the center of the screen.
3. Connect the output of the a-f oscillator first to the H pin jack, then to the V pin jack, and observe that this voltage produces horizontal and vertical lines, respectively, on the screen.
4. Vary the output voltage of the a-f oscillator, and note that the length of the traces varies in direct proportion to the output voltage.
5. Call an instructor, and demonstrate to him the effects noted in steps 2, 3, and 4. These indications show that the oscilloscope is functioning properly.

Instructor's initials______

6. The instructor will now insert trouble into your equipment. Locate and remove this trouble, and fill out the attached JOB SHEET. Return the defective parts to the instructor.

Instructor's initials______

7. If time permits, the instructor will insert additional troubles into the circuit. Remove these troubles, make a record on the JOB SHEET, and return the defective parts, as in step 6.

Instructor's initials______

CONCLUSIONS

Describe in detail the trouble-shooting procedure used in removing the troubles that were inserted in the equipment. Stress the following points:

1. Symptoms of improper operation that were observed.
2. Which circuits were suspected, and why.
3. Preliminary checks made in order to eliminate all but one circuit as a possible source of trouble.
4. Procedure used in locating the defective part within that circuit.

This discussion is to be much more detailed than the one recorded on the JOB SHEET. Write a discussion that, in your opinion, will be valuable to you later in planning a course on the trouble-shooting and maintenance of oscilloscopes.

JOB SHEET

Student's Name____

Section ____

INDICATION (no trace, distortion, hum pickup, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE OSCILLOSCOPE.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)

LABORATORY PLAN No. 33

SUBJECT

Special oscilloscope circuits—blanking and intensifying.

OBJECTIVE

To help the students in studying the operation of the blanking and intensifying circuits.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis.
2. Cathode Follower Chassis.
3. One-Shot Multivibrator Chassis.
4. Saw-Tooth Generator Chassis.
5. Mixer Chassis.
6. Five-inch oscilloscope with leads.
7. A-F oscillator with leads.
8. Additional plug-in parts, to be determined by the student.
9. Laboratory Chassis Mounting Rack.
10. Power Supply Chassis.

INTRODUCTION

The blanking circuit is used to prevent electrons from striking the screen of an oscilloscope during the flyback time of the observed trace. The intensifying circuit makes visible a sweep of very short duration which normally does not appear on the screen.

SUBJECT MATERIAL

1. Supervise the process of setting up the equipment. (The students are to rearrange the plug-in parts of the Mixer Chassis so that the circuit performs as a cathode follower.) When the students have obtained the desired saw-tooth waveform, initial their workbooks.

2. Conduct a brief demonstration, indicating what the class should expect in the blanking section of the EXPERIMENT. Refer to the steps given in that section.

3. Supervise the study of the operation of the intensifying circuits. Insist upon neat and accurately drawn waveforms.

CONCLUSIONS

As brought out in this EXPERIMENT, there is a definite need for both the blanking and intensifying circuits in radar. The former is essential to avoid confusion in interpreting results on the screen of the cathode-ray tube, and the latter is used in those radar systems where the target echo has the appearance of a bright spot.

EXPERIMENT No. 33

SUBJECT

Special oscilloscope circuits—blanking and intensifying.

OBJECTIVE

To learn of the need for blanking and intensifying circuits in an oscilloscope, and to study the operation of such circuits.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis.
2. Cathode Follower Chassis.
3. One-Shot Multivibrator Chassis.
4. Saw-Tooth Generator Chassis.
5. Mixer Chassis.
6. Five-inch oscilloscope with leads.
7. A-F oscillator with leads.
8. Additional plug-in parts, to be determined by the student.
9. Laboratory Chassis Mounting Rack.
10. Power Supply Chassis.

INSTRUCTIONS

In radar systems, the cathode-ray tube is used as an indicator in the measurement of the time required for the transmitted pulse to reach a target and to return. To perform this function, the trace is calibrated in terms of distance. One method of calibration uses a series of bright spots that appear on the trace at intervals of 1 mile, 5 miles, 10 miles, etc. Spots of this description can be obtained by "intensifying" the trace at suitable time intervals.

The trace on most scopes is generated by a saw-tooth voltage. Since the decay time of this voltage cannot be reduced to zero, it appears on the scope as a return trace, sometimes called a "flyback trace." Unfortunately, this trace gives very confusing information; it permits the appearance, upon the scope, of unwanted target "echoes" that arrive after the forward stroke has ended. The confusion becomes acute if the saw-tooth has a long "resting period" between forward sweeps. In order to prevent the return trace from appearing on the scope, a "blanking" (gating) pulse is applied to the grid of the cathode-ray tube. This blanking pulse disables the scope during the intervals when the flyback is occurring.

This EXPERIMENT will show some of the methods used to blank or intensify selected portions of the scope trace.

PROCEDURE

Blanking

1. Set up the equipment as shown in the block diagram of figure 1.

2. Rearrange the plug-in parts in the Mixer Chassis so that the mixer acts as a cathode follower.

Use only one of the mixer channels, to provide a cathode-follower circuit having a variable gain. This makes it possible to vary the amount of

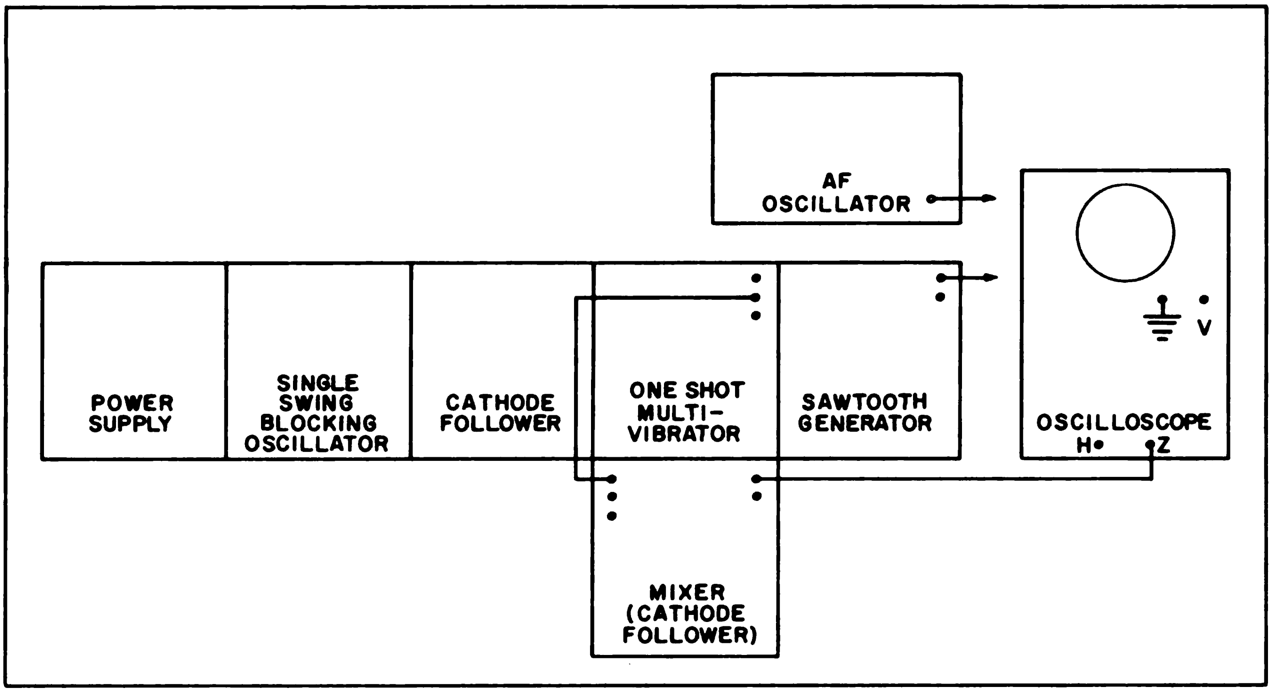
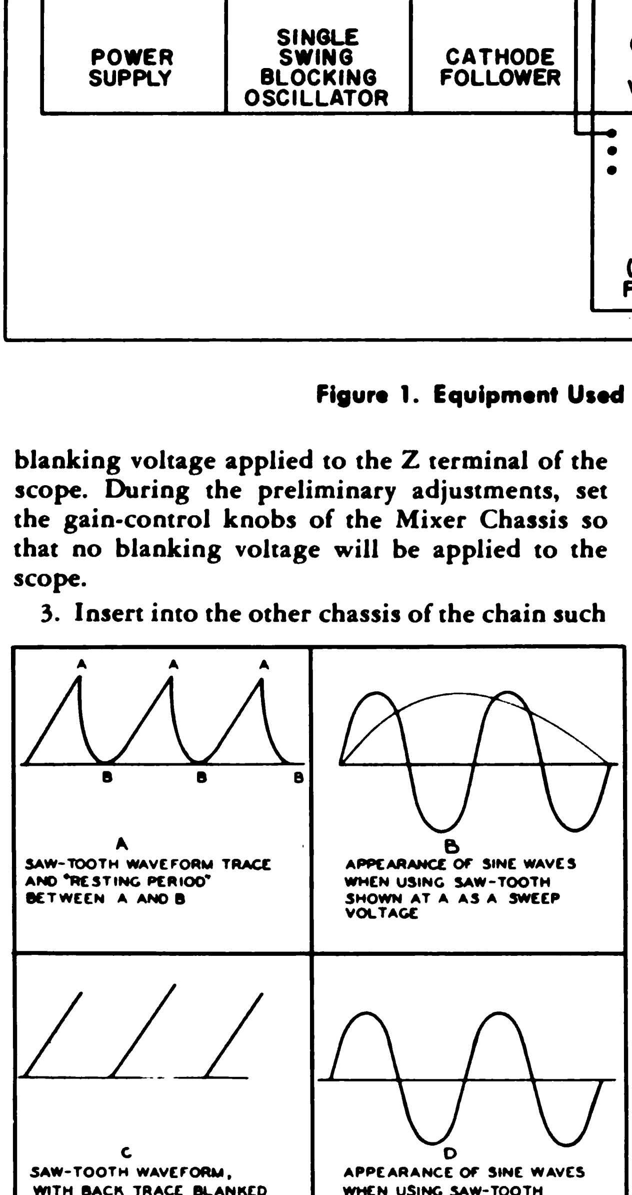


Figure 1. Equipment Used for Blanking the Back Trace

blanking voltage applied to the Z terminal of the scope. During the preliminary adjustments, set the gain-control knobs of the Mixer Chassis so that no blanking voltage will be applied to the scope.

3. Insert into the other chassis of the chain such plug-in parts as may be necessary, in order to produce saw-tooth waves of good linearity, having a pulse repetition frequency of 60 p.p.s.



A
SAW-TOOTH WAVEFORM TRACE AND "RESTING PERIOD" BETWEEN A AND B

B
APPEARANCE OF SINE WAVES WHEN USING SAW-TOOTH SHOWN AT A AS A SWEEP VOLTAGE

C
SAW-TOOTH WAVEFORM, WITH BACK TRACE BLANKED

D
APPEARANCE OF SINE WAVES WHEN USING SAW-TOOTH SHOWN AT C AS A SWEEP VOLTAGE

Figure 2. Waveforms Obtained With Blanking and Without Blanking of Sweep-Voltage Flyback

Since the student is already familiar with all of the chassis to be used in this EXPERIMENT, determination of the proper parts and potentiometer adjustments is left to his own judgment. The instructor's approval must be obtained after the desired saw-tooth waveform has been produced on the scope.

Instructor's initials______

4. Check the Mixer Chassis, to make sure that no blanking voltage is being applied to the Z terminal of the scope. Then, at A in figure 2, draw the saw-tooth waveform observed at the OUTPUT jack of the saw-tooth generator. Note particularly the portion of the curve over which flyback occurs. Label the beginning of the flyback trace "A," and label the end of the flyback "B."

5. Connect the OUTPUT jack of the saw-tooth generator to the horizontal-input terminal of the scope, and turn the scope switch that disables the internal sweep oscillator. This should result in a straight horizontal line across the scope face, due to the sweeping action of the saw-tooth waveform produced by the laboratory chassis setup.

6. Connect the vertical-input terminal of the scope to the a-f oscillator, and adjust the frequency

of the oscillator until several sine waves appear on the scope.

7. At B in figure 2, sketch the trace obtained in step 6, being careful to include the flyback trace. Label the beginning of the flyback (at the right-hand side of the screen) "A," and label the end of the flyback "B," to correspond with the waveform drawn at A in figure 2. Interpretation of this trace requires careful thought. Do not jump to conclusions.

8. Disconnect the a-f oscillator from the vertical input of the scope and connect the vertical scope terminal to the OUTPUT jack of the saw-tooth generator. Turn the frequency-selector switch of the scope so as to place the internal sweep oscillator in operation. This should result in the reappearance upon the screen of the saw-tooth waveform from the Saw-Tooth Generator Chassis.

9. Advance the gain-control knob of the Mixer Chassis slowly, noting that the flyback trace becomes progressively dimmer, and finally disappears altogether. Adjust the mixer gain-control knob to the point where the flyback trace just disappears. At C in figure 2, record the trace now appearing on the scope. Do not disturb the present setting of the mixer gain-control knob until instructed to do so in step 10.

10. Transfer the output of the saw-tooth generator to the horizontal-input terminal of the scope, disable the scope's internal sweep generator, and apply a sine-wave signal from the a-f oscillator to the vertical-input terminal of the scope. This is the same procedure used in steps 5 and 6, above. It should result in a scope trace showing several cycles of a sine wave *with no back trace.* Record this waveform at D in figure 2. Then vary the gain-control knob at the Mixer Chassis, noting the gradual appearance and disappearance of the back trace. Check what you see against the drawing at B in figure 2.

The four traces of figure 2 now show:

At A, the unavoidable flyback occurring in all saw-tooth waveforms.

At B, the confusing back trace produced on a scope when such a saw-tooth waveform is used as a sweep voltage—especially if the saw-tooth has a long "resting period" between forward strokes.

At C, the complete elimination of the flyback trace by means of blanking.

At D, the absence of a back trace when this blanked saw-tooth waveform is used as a sweep voltage.

Intensifying

1. Switch the scope to internal sweep. Connect the output of the saw-tooth generator to the external sync terminal on the scope and switch the sync switch to external. Connect the output of the mixer to the Z amplifier input of the scope. Make sure one output of the one-shot multivibrator is applied to the proper input of the mixer, which is being used as a cathode follower. Turn the mixer control for maximum blanking and adjust the scope so that you have 3 or 4 bright spots or short dashes. Turn the intensity of the scope down so that blanking is complete between the spots.

CONCLUSIONS

1. Discuss the importance of blanking, using figure 2 as a basis for your remarks.

2. What type of trace would be obtained at C in figure 2 if a plate-loaded amplifier were used between the one-shot multivibrator and the Z terminal of the scope, instead of the cathode-follower used in this EXPERIMENT? Explain.

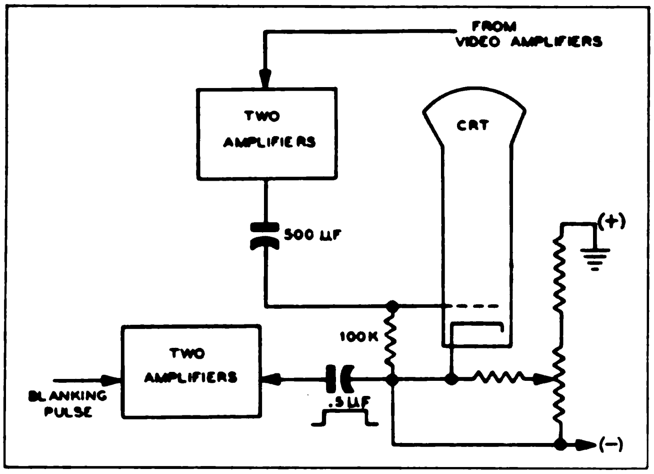
The blanking pulse would be inverted by the plate-loaded amplifier, resulting in blanking the forward trace on the screen of the oscilloscope, and permitting only the return trace to be seen.

3. How is blanking accomplished in commercial oscilloscopes? Give a specific example.

Using the DuMont type 208 as an example,

blanking is accomplished by differentiating the saw-tooth pulse from the cathode of the first horizontal-deflection amplifier. This differentiating curcuit is located at the grid of the cathode-ray tube, and places a negative pulse on the cathode-ray tube grid during flyback intervals.

4. Suppose that the grid of a cathode-ray tube is already being used for video signals, and cannot be employed for blanking, yet blanking of the scope is desired. Draw a diagram of connections that will provide the desired blanking. Explain the operation of the blanking circuit.



Suggested Drawing for Question 4

LABORATORY PLAN No. 34

SUBJECT

Construction and analysis of a simplified radar system.

OBJECTIVE

To familiarize the students with the operation of a simplified radar system; to have them study the waveforms, voltage amplitudes, and frequencies developed in this simplified system.

MATERIAL REQUIRED

Since certain laboratory chassis can be modified to perform functions other than those indicated by their basic names, a given chassis may be referred to by different functional names in different EXPERIMENTS. For this reason, a series of identifying numbers has been assigned to cover all basic chassis. These numbers, given in parentheses, are associated with references to the chassis in the text and block diagrams of this EXPERIMENT and others to follow. The basic name of each chassis is given in the list under MATERIAL REQUIRED.

1. Single-Swing Blocking Oscillator Chassis (12).
2. Diode Step Counter Chassis (17).
3. Triggered Blocking Oscillator Chassis (18).
4. Cathode Follower Chassis (4).
5. One-Shot Multivibrator Chassis (13).
6. Vacuum-Tube Saw-tooth Generator Chassis (2).
7. Mixer Chassis (6).
8. Five-inch oscilloscope with leads.
9. A-F oscillator with leads.
10. Vacuum-tube voltmeter with leads.
11. Laboratory Chassis Mounting Rack.
12. Power Supply Chassis (22).

INTRODUCTION

The system studied in this EXPERIMENT is a good example of a simplified radar chain. The chassis used in making up the radar chain will produce pulses from a master oscillator that will be seen on the scope screen.

The successful employment of pulse-modulated radar systems depends primarily on the ability to measure distance in terms of time. A time scale is provided by using a linear sweep to produce a known rate of motion of the electron beam across the screen of the scope. By measuring the time in microseconds between the transmitted pulse and the return echo pulse, the distance may be determined between the target and the radar antenna. Therefore these chassis, used in this radar system for making time measurements, are the basis of all radar range-measuring devices.

SUBJECT MATERIAL

1. Check to see if the students have connected the equipment as shown in the block diagram in this EXPERIMENT. They should make the necessary connections and adjustments, as prescribed in the EXPERIMENT.

2. Have the students make a careful observation of the waveforms that were taken, and supervise the construction of a synchrogram.

3. Check all waveforms carefully, and initial each student's work before allowing him to proceed.

4. Make certain that the students measure proper sweep durations of the gate width pulse, and that they measure correct time lags in the sweep circuits used.

5. Keep a constant bench-to-bench check on the student's technique and procedure.

CONCLUSIONS

This EXPERIMENT on the simplified radar system has been selected because it is a relatively simple system which illustrates the fundamental principles and circuit applications used in radar. The radar chain used will permit the measurement of time between pulses; therefore the distance between the target and the radar antenna may be determined.

EXPERIMENT No. 34

SUBJECT

Construction and analysis of a simplified radar system.

OBJECTIVE

To assemble a simplified radar system capable of producing a synchronized sweep and a system of range markers; to study the waveforms, voltage amplitudes, and frequencies developed; and to become familiar with the general concept of time measurements, as employed in radar.

MATERIAL REQUIRED

Since certain laboratory chassis can be modified to perform functions other than those indicated by their basic names, a given chassis may be referred to by different functional names in different EXPERIMENTS. For this reason, a series of identifying numbers has been assigned to cover all basic chassis. These numbers, given in parentheses, are associated with references to the chassis in the text and block diagrams of this EXPERIMENT and others to follow. The basic name of each chassis is given in the list under MATERIAL REQUIRED.

1. Single-Swing Blocking Oscillator Chassis (12).
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5. One-Shot Multivibrator Chassis (13).
6. Vacuum-Tube Saw-tooth Generator Chassis (2).
7. Five-inch oscilloscope with leads.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.
10. Laboratory Chassis Mounting Rack.
11. Power Supply Chassis (22).

INSTRUCTIONS

The system to be studied during this EXPERIMENT is a good example of a simple radar chain used in time measurements. More elaborate systems will be studied later in the course, but this EXPERIMENT is aimed at familiarizing the student with the basic idea of the time (and consequently distance) measurements that form the basis of all radar techniques.

The operation of the system is as follows:

The single-swing blocking oscillator (12) acts as a master oscillator. The positive pulses occurring at its cathode are used to time the operation of the entire system. In this respect, it acts in much the same manner as does a master oscillator in a radio transmitter.

The positive timing pulses produced by the blocking oscillator are applied to a diode step counter (17) and a triggered blocking oscillator (18), which "count down" the trigger pulses and deliver one high-amplitude sine-wave cycle at every fifth trigger pulse (variable).

A cathode follower (4) is used to attenuate this positive pulse until the amplitude is suitable for triggering the one-shot multivibrator (13).

The one-shot multivibrator, triggered by the output of the cathode follower, produces a negative gate pulse of adjustable width. The gate starts at the same instant as the trigger pulse, and remains highly negative for a time interval depending upon the time constant of the multivibrator grid-leak circuit. When the grid of the cut-off tube relaxes to above cutoff, the negative gate disappears.

The negative gate pulse, when applied to the grid of a vacuum-tube saw-tooth generator (2), cuts off the tube and allows its plate voltage to rise almost linearly. This linear voltage rise continues until the end of the gate pulse, when the tube unblocks, and the output voltage falls abruptly to zero. The result is a saw-tooth waveform which starts at the instant the trigger pulse arrives, and rises steadily for the duration of the gate, then falls quickly to zero when the gate ends.

This saw-tooth waveform is applied to the horizontal-deflection plates of a scope, causing the spot to trace a horizontal line across the screen. The time required for the spot to complete one excursion across the screen is exactly the same as the time elapsing between the instant the trigger pulse arrives and the instant the negative gate ends.

In order to measure the time duration of the sweep with fair accuracy, marker pips are placed on the sweep trace. These pips are obtained directly from the cathode of the single-swing blocking oscillator (master oscillator), and are applied to the vertical-deflection plates of the scope. With this oscillator operating at a frequency of 60 cycles per second, the trigger pulses occur at intervals of 16,666 microseconds. If the pips mark off the sweep trace into three divisions, it is obvious that the sweep duration is3 × 16,666 (or approximately 50,000) microseconds long.

The student will be required to perform various time measurements with this equipment. The methods to be learned in this EXPERIMENT will be used throughout the rest of the course, and must become as familiar as the methods of measuring voltage or frequency.

PROCEDURE

Connecting and Testing

1. Replace SS-1 in the single-swing blocking oscillator with a 100k resistor. Leave SS-2 in normal position. Remove R2 and replace R1 with a shorting strip in the triggered blocking oscillator. Put SS-1 in normal position in the one-shot multivibrator.

2. Connect the equipment as shown in the block diagram, figure 1.

3. Connect the scope lead to the OUTPUT jack (cathode) of the single-swing blocking oscillator, and adjust the oscillator frequency to about 60 cyles per second.

Observe that the output waveform is a series of very narrow positive pulses. These pulses may not be visible until they are completely stationary on the screen. An easy way of observing them is to turn up the vertical-amplitude control of the scope and note a line of sharp discontinuities along the horizontal line. The faint vertical lines marking the sides of the trigger pulses may not be visible, but blank spaces evenly distributed along the horizontal sweep will indicate their presence. When these blank spaces have been made stationary by adjustment of the sweep-frequency and sync controls, the vertical amplitude can be turned down until the positive pulses are visible.

4. Move the scope lead to the OUTPUT jack of the diode step counter. Adjust the sweep frequency of the scope until a flight of "stair-steps" appears on the screen. Make simultaneous adjustments of the scope frequency control and the bias control of the triggered blocking oscillator until a stationary pattern of five steps appears on the screen.

5. Transfer the scope lead to the OUTPUT jack of the triggered blocking oscillator. Observe that a single cycle of roughly sinusoidal voltage is being produced at this point. Adjust the scope frequency controls until this one cycle remains stationary on the screen. Then move the scope lead to the OUTPUT jack of the single-swing blocking oscillator. Note that five cycles of the oscillator output waveform appear on the screen. This observation checks the step-counting circuit, which is supposed to be dividing by 5 the trigger pulses fed into it.

6. Connect the scope lead to the OUTPUT jack of the cathode follower. Vary the bias control knob R2, and note the effect upon the output waveform.

7. Connect the scope lead to the OUTPUT jack of the one-shot multivibrator. Observe that a square wave is being produced. Vary the multivibrator grid-leak potentiometer, R6, and note that the trailing edge of the negative gate moves back and forth.

It may be found that the one-shot multivibrator does not trigger properly. Wide adjustment of trigger amplitude is possible by varying the bias on the cathode follower. Vary the bias while watching the output waveform from the OUTPUT jack of the multivibrator, and note the upper and lower limits of the amplitude range over which triggering is satisfactory. Then adjust the bias to the middle of this range.

8. Transfer the scope lead to the OUTPUT jack of the saw-tooth generator, and observe that a fairly linear saw-tooth waveform is being produced. Vary the grid-leak potentiometer, R6, of the one-shot multivibrator, and observe that the width of the saw-tooth wave changes.

9. Remove the vertical scope lead from the OUTPUT jack of the saw-tooth generator, and connect that jack to the input binding post of the scope's horizontal amplifier. Turn the frequency-selector switch of the scope so as to connect, to the horizontal amplifier, the binding post to which the saw-tooth generator is connected. Note that a horizontal trace appears across the scope screen, and that the length of the trace can be adjusted by means of the horizontal-gain control of the scope. Note that the trace length can also be changed by varying the width of the gate produced by the one-shot multivibrator (by changing the setting of the multivibrator potentiometer), and by changing the amplitude of the saw-tooth waveform produced by the saw-tooth generator (by varying the setting of the generator potentiometer).

10. Now connect the vertical lead of the scope to the OUTPUT jack of the single-swing blocking oscillator. A row of positive marker pips should appear on the scope trace. The amplitude of these pips can be varied by changing the setting of the scope's vertical gain control. The number of pips appearing on the trace will depend upon the duration of the trace, and can be varied by chang-

ing the width of the multivibrator gate. The number of pips *cannot* be changed by varying the scope's horizontal gain control or the amplitude control of the saw-tooth generator output, because these controls change only the voltage applied to the horizontal plates; they have nothing whatever to do with the length of time it takes for the spot to complete one excursion across the screen.

11. Have an instructor observe the sweep, with its marker pips, and explain to him what you have learned thus far about the process of time measurement.

Instructor's initials______

Construction of a Synchrogram

1. In the space provided in figure 2, construct a synchrogram of the six waveforms developed in this equipment. Draw the actual waveforms observed, and be very careful to place them in correct relationship with each other. In the case of the step pattern, record the height (in volts) of each step.

2. Enter in figure 2 the peak amplitudes of all voltages involved.

3. Measure and record, in figure 2, the time in microseconds elapsing between the leading edges of successive pulses. In the case of the gate pulse produced by the multivibrator, record the width of the negative gate and of the positive pulse that separates two adjacent negative gates.

Measurement of Sweep Duration by Comparison with Gate Width

1. Set the charging-resistance potentiometer, R2, of the saw-tooth generator to its maximum-resistance position.

2. Open the negative gate of the multivibrator as wide as possible (that is, make the negative pulse as wide as variation of the multivibrator potentiometer will permit). Carefully measure and record the width of the gate.

Maximum gate width_ microseconds

3. How does the duration of the sweep compare with the duration of the gate pulse? Explain fully.

The durations are the same, because the sweep voltage is produced only during the cutoff period of the saw-tooth generator, and the duration of cutoff, in turn, is determined by the duration of the gate pulse.

Estimation of Sweep Duration by Means of Range Markers

1. Using the same gate width and the maximum-resistance setting of the saw-tooth generator potentiometer, adjust the horizontal-gain control of the scope to a point where the sweep covers 40 scale divisions.

2. In figure 3, carefully draw the sweep and the range markers observed. Indicate the time elapsing between each pair of adjacent range markers.

3. Estimate as closely as possible the duration of those portions of the sweep that do not lie between range markers.

Although the range markers are not spaced evenly, it is known that each is separated from adjacent marks by exactly the same time interval. If three range marks appear on the sweep, if the sweep projects a short distance to the right of the last range mark, and if no evidence of a range mark is observed at the extreme left-hand end of the sweep, exact time measurements can be made of only those portions of the trace that lie between range marks. The duration of the short projection at the right must be estimated, by comparing its length with that of the segment of the trace lying between the two previous range marks. Remember to make allowance for the fact that the scale is not linear, but exponential. The length of the segment between the left-hand end of the sweep and the first range marker can be estimated in the same way.

It is obvious, therefore, that range marks are useful in the quick estimation of the distance from the radar equipment to moving targets. Range markers are widely used for this purpose in radar scanning equipment. The more accurate range notch (to be studied later in the course) is employed in gun-laying and fire control equipment, where higher precision is required.

Measurement of Time Lag in the Sweep Circuits

1. Adjust the width of the multivibrator gate (by varying the multivibrator potentiometer) until the last visible range marker rests exactly on the right-hand end of the sweep trace.

2. In figure 4, draw accurately the trace obtained.

3. Measure the width of the multivibrator gate, in microseconds.

Gate width_____microseconds

4. Measure the frequency of the marker pulses, and calculate the interval of time separating the pulses.

Interval between markers____ microseconds

5. Calculate the time elapsing between the beginning of the sweep and the first range marker:

a. Total duration of the sweep (same as the gate width), microseconds.

b. Duration of that portion of the trace lying between the first and last range markers,_____ microseconds.

c. Duration of that portion of the trace lying between the start of the sweep and the first range marker,_____microseconds.

CONCLUSIONS

1. It was noted that adjustment of the potentiometer of the one-shot multivibrator allowed the *right-hand* end of the sweep to be lengthened or shortened, at will. If the gate pulse that drove the vacuum-tube generator had been taken from the other plate of the multivibrator, instead of the OUTPUT jack, the *left-hand* end of the sweep would have been lengthened and shortened, while the right-hand end would have remained unaffected. Explain why this is so, drawing the necessary synchrograms.

With the output taken from the OUTPUT jack, the right-hand edge of the negative gate is variable, and the right-hand end of the sweep trace lengthens and shortens. With the output taken from the other plate, the left-hand edge of the trace is variable and the left-hand end of the sweep is lengthened and shortened.

2. In Measurement of Time Lag in the Sweep Circuits, it was determined that a short time interval elapsed between the instant when the trigger pulse impinged upon the sweep circuit and the instant when the sweep started. Discuss fully the possible causes of such a delay.

The output of the triggered blocking oscillator is a sine wave, the first half-cycle of which is always negative. Only the positive alternation is useful; therefore the negative alternation is eliminated by feeding this sine wave into a cathode follower. Since the sweep cannot start until the positive alternation starts, a time lag occurs.

A slight phase shift introduced by coupling capacitor may also cause a slight delay.

3. Suppose that it is desired to produce a sweep with range markers that will permit the rapid estimation of distance to moving targets within the range from 1 mile to 5 miles. It is desirable to have range marks at 1-mile intervals over the entire sweep. Using a system similar to the one studied during this EXPERIMENT, at what frequency must the single-swing blocking oscillator be operated? What counting ratio would you use in the step-counter circuit? How wide would you make the gate pulse? Show all your work, and draw a synchrogram of the waveforms that would be produced, indicating the time intervals involved.

Since one radar range mile is 12.3μ sec. long, the single swing blocking oscillator must be operated at a frequency of 81.3 kc. (the reciprocal of 12.3μ sec.), to produce range markers for each radar range mile. The step counter should be so adjusted that the sweep will rise for 61.5μ sec. (five radar range miles) and rest for an equal period of time. This long resting time prevents reception of echoes from distant targets on the second sweep. This is accomplished by making the step counter count at a ratio of 10 to 1. The gate pulse produced by the one-shot multivibrator should be 61.5μ sec. long so that five range markers will appear on the indicator screen.

Drawing for Question 3 of the Conclusions

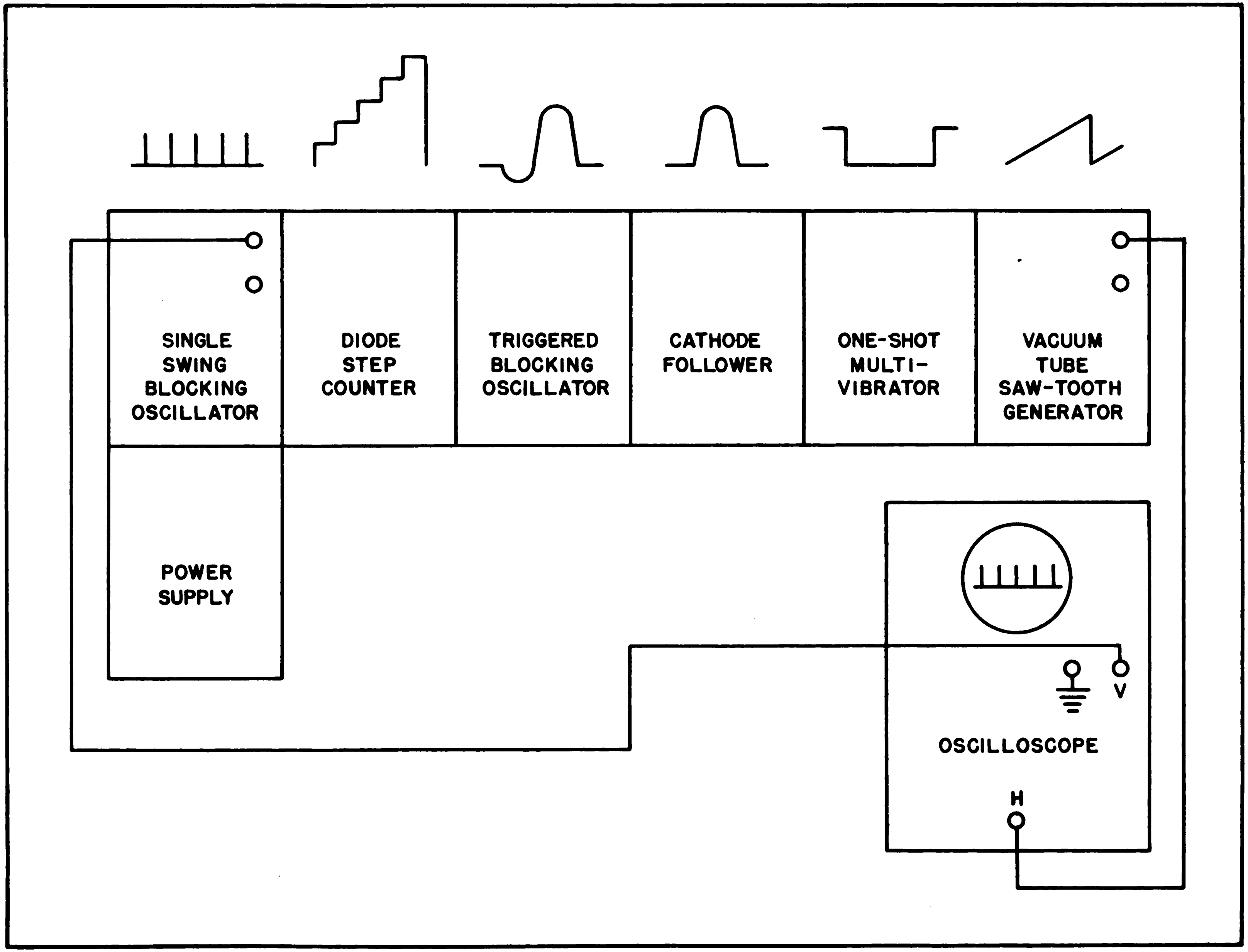
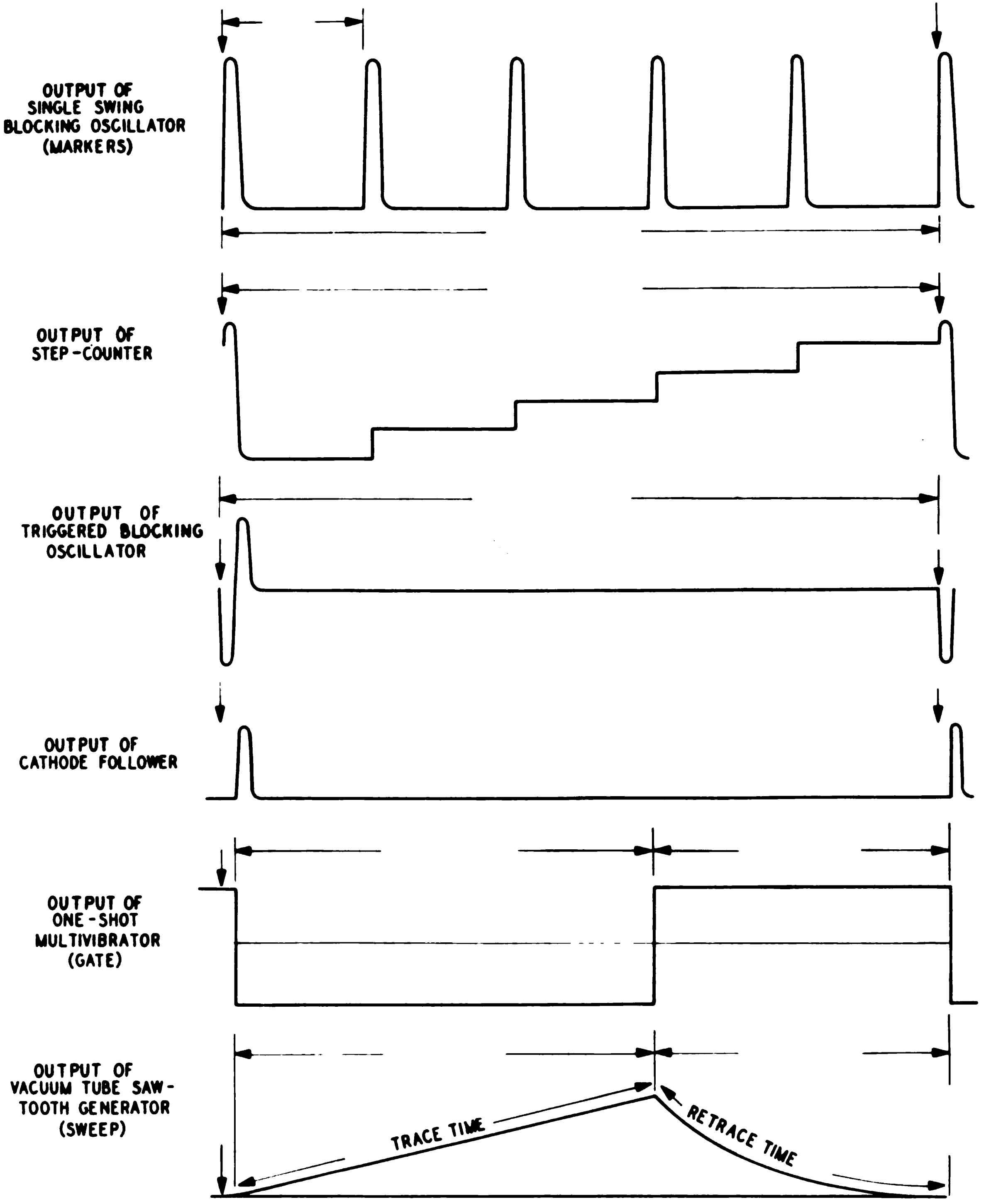

SINGLE SWING BLOCKING OSCILLATOR
DIODE STEP COUNTER
TRIGGERED BLOCKING OSCILLATOR
CATHODE FOLLOWER
ONE-SHOT MULTI-VIBRATOR
VACUUM TUBE SAW-TOOTH GENERATOR
POWER SUPPLY
V
OSCILLOSCOPE
H

Figure 1. Block Diagram of a Simplified Radar System



NOTES:
VOLTAGE READINGS WILL BE DEPENDENT UPON THE SETTINGS OF THE CONTROLS IN THE SIMPLIFIED RADAR SYSTEM

Figure 2. Synchrogram of Waveforms Developed in Simplified Radar System

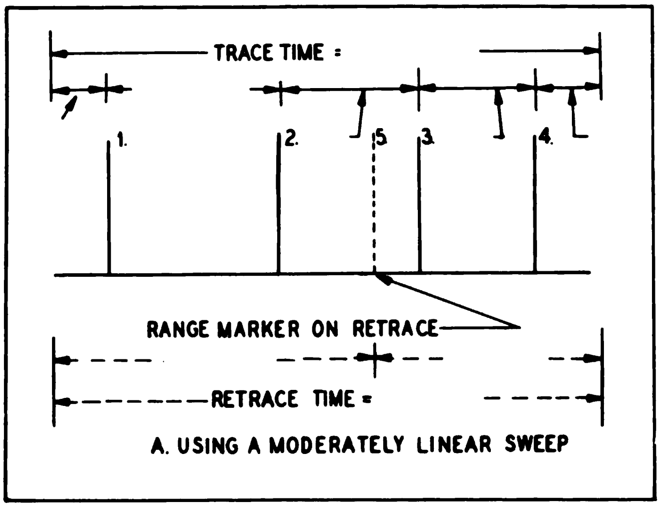
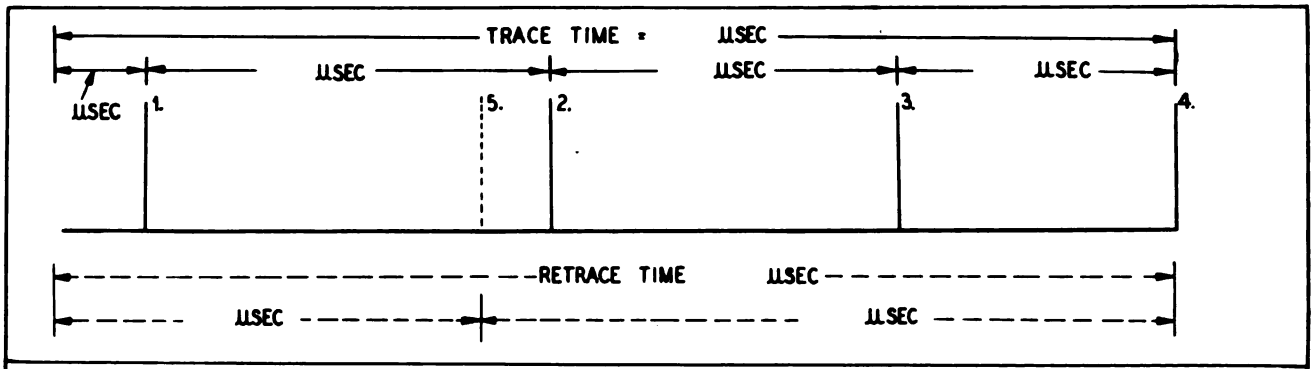


Figure 3. Distribution of Range Marks upon Nonlinear Sweeps



LENGTH OF SWEEP = μSEC
FIRST TO LAST MARKER = μSEC (TRACE TIME)
START OF TRACE TO FIRST MARKER = μSEC
TIME BETWEEN MARKERS = μSEC
TIME DELAY = μSEC

Figure 4. Data Used in Determining the Time Lag Existing in a Sweep Circuit

LABORATORY PLAN No. 35

SUBJECT

Trouble shooting a basic radar system.

OBJECTIVE

To familiarize the students with the trouble-shooting methods for a basic radar chain, and to develop a step-by-step procedure for finding and removing troubles.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Diode Step Counter Chassis (17).
3. Triggered Blocking Oscillator Chassis (18).
4. Cathode Follower Chassis (4).
5. One-Shot Multivibrator Chassis (13).
6. Vacuum-Tube Saw-tooth Generator Chassis (2).
7. Five-inch oscilloscope with leads.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.
10. Laboratory Chassis Mounting Rack.
11. Power Supply Chassis (22).

INTRODUCTION

The procedure used in this EXPERIMENT will be used in all the trouble-shooting EXPERIMENTS that follow. The student's ability to work out for himself a method of localizing trouble to a functional unit of this equipment, isolating the trouble to one particular circuit, and locating the trouble in a specific stage within the faulty circuit, is particularly important.

The sequence of operations given above is simplified, practical, and convenient to use, and results in faster and more efficient service.

SUBJECT MATERIAL

1. Before the students begin the EXPERIMENT, have them draw trouble-shooting charts. Approve these charts before allowing the students to continue.

2. Have the students set up the basic radar system used in the previous EXPERIMENT and check its operation, to see that the system is operating properly. Insert troubles into the radar system, so that the students may locate them.

3. Be sure the students follow the trouble-shooting procedure, and that they fill out the attached JOB SHEET.

4. Keep a constant bench-to-bench check on the students' technique and the trouble-shooting procedure used; also initial the students' JOB SHEETS when they have completed the EXPERIMENT.

CONCLUSIONS

The speed with which the cause of improper functioning or failure of a specific piece of equipment can be corrected is of prime importance. The system of trouble shooting which has been used in this EXPERIMENT will save much time and cut down operational losses. The use of "Localize, Isolate, and Locate" teaches the technician to follow a logical, standardized trouble-shooting technique.

EXPERIMENT No. 35

SUBJECT

Trouble shooting a basic radar system.

OBJECTIVE

To become familiar with the usual indications of trouble in this type of radar chain, and to develop a step-by-step procedure for finding and removing troubles.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Diode Step Counter Chassis (17).
3. Triggered Blocking Oscillator Chassis (18).
4. Cathode Follower Chassis (4).
5. One-Shot Multivibrator Chassis (13).
6. Vacuum-Tube Saw-tooth Generator Chassis (2).
7. Five-inch oscilloscope with leads.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.
10. Laboratory Chassis Mounting Rack.
11. Power Supply Chassis (22).

INSTRUCTIONS

While a screwdriver, a moist finger, and a sensitive ear may be adequate equipment with which to make emergency repairs upon a radio receiver, nothing but precision methods are satisfactory for the trouble-shooting of radar equipment. A thorough familiarity with the wave-forms normally encountered in radar circuits, a working knowledge of the frequencies and voltages to be expected, and a systematic approach to the problem are as much a part of the radar man's equipment as are his voltmeter and his oscilloscope. The student should realize that a radio receiver ordinarily has fewer than a dozen tubes, while one type of airborne radar employs nearly 300 tubes.

This EXPERIMENT, and all the trouble-shooting EXPERIMENTS to follow, will be aimed at developing in the student an ability to work out for himself a common-sense method of localizing trouble to one unit of his equipment, isolating the difficulty to one particular circuit, and locating the defective part or the improper adjustment. The quickest way for the student to develop such a faculty is to draw up sample procedures on equipment with which he is already thoroughly familiar, such as the laboratory chassis with which he has been working for the past several months. This method will be followed, and the student will receive credit not only for the speed with which he can eliminate troubles, but for the systematic method by which he conducts his trouble shooting.

PROCEDURE

1. Before coming to the laboratory, draw up a trouble-shooting procedure suitable for locating troubles in the simplified radar system studied in the previous EXPERIMENT. This procedure should be written along the same lines as those used in the Basic Electronic Systems course, in connection with radio receivers and transmitters. Follow the Localize, Isolate, and Locate formula, and try to arrive at the cause of the trouble with a minimum of tests. Use Major, Key, and Secondary Test Points of your own choice. Submit this procedure to your instructor for his approval before proceeding. (Use page 324.)

Instructor's initials______

2. Set up the Basic Radar System studied in the previous EXPERIMENT. When it is working properly, the instructor will insert troubles into the system.

Instructor's initials______

3. Following the trouble-shooting procedure you have drawn up for this equipment, locate and remove the troubles. As you work, make such notes as may be useful in eliminating similar troubles in future EXPERIMENTS. Fill out the attached JOB SHEET, giving full details of the symptoms observed, the procedure followed, the results obtained, and the troubles found.

4. Have the instructor verify your success in locating all of the troubles he inserted.

Instructor's initials______

5. If time permits, you may ask that additional troubles be inserted in your equipment, and may remove them for extra credit.

Instructor's initials______

CONCLUSIONS

1. Suppose that it is found impossible to obtain a sweep wide enough to fill the scope screen,

although the amplitude of the range markers appeared normal. How would you proceed in finding the trouble?

a. Check the amplitude of the saw-tooth generator output; if normal, check the horizontal amplifier of the scope.

b. Check the RC constant of the saw-tooth generator, to see whether the components have changed value. A decrease in RC time constant will cause the sweep width to decrease.

c. Check the gate pulse applied to the saw-tooth generator, to see whether it has the proper width. Adjust the width of the negative gate pulse until the amplitude of the saw-tooth generator output is correct.

d. Check the setting of the horizontal-amplifier gain control on the cathode-ray oscilloscope. Check the sensitivity of the horizontal amplifier of the oscilloscope.

2. What would be the most likely causes of an excessive number of range markers?

a. If the negative pulse of the one-shot multivibrator is too wide, it will cause the time duration of the saw-tooth generator to be too long, resulting in an excessive number of range markers.

b. If the repetition rate of the single-swing blocking oscillator is too high, it will cause an excessive number of range markers to appear on the scope. This is due to a decrease in RC time constant in the grid circuit of the blocking oscillator.

3. What sources of trouble might result in excessive crowding of range markers at the right-hand end of the sweep?

A nonlinear saw-tooth rise causes an exponential sweep. Nonlinearity might indicate that:

a. The RC time constant in the grid circuit of the one-shot multivibrator is too short.

b. The negative gate pulse to the saw-tooth generator is too long.

4. How would you proceed in finding the reason for absence of sweep, although suitable trigger pulses were present at the input of the one-shot multivibrator?

a. Check the input to the saw-tooth generator with the scope, to see whether the proper waveform is present.

b. If the input to the saw-tooth generator is improper, check the output of the one-shot multivibrator; the negative gate pulse should be present.

c. If the output is improper, the trouble is in the multivibrator. Make voltage and resistance checks to locate the faulty component.

d. If the input to the saw-tooth generator is correct, check the output, to see whether a saw-tooth waveform is present. If the output is improper, make voltage measurements, to locate the faulty component in the saw-tooth generator circuit.

e. If the output waveform of the saw-tooth generator is correct check the scope to see whether its horizontal sweep is present. Absence of horizontal sweep indicates that there is trouble in the horizontal amplifier; make voltage measurements, to locate the faulty component in the circuit.

5. What would be your first trouble-shooting steps if it were found that neither sweep nor markers were obtainable?

Since the trouble affects both the horizontal and vertical output, the defect must be in some circuit upon which the horizontal and vertical circuits are dependent.

a. Power supply.

Check the power supply, to determine whether all voltages are their proper operating values.

b. Single-swing blocking oscillator.

Check the output of the single-swing blocking oscillator. If the output is improper, make voltage measurements in the circuit, to locate the faulty component.

JOB SHEET

STUDENT'S NAME____

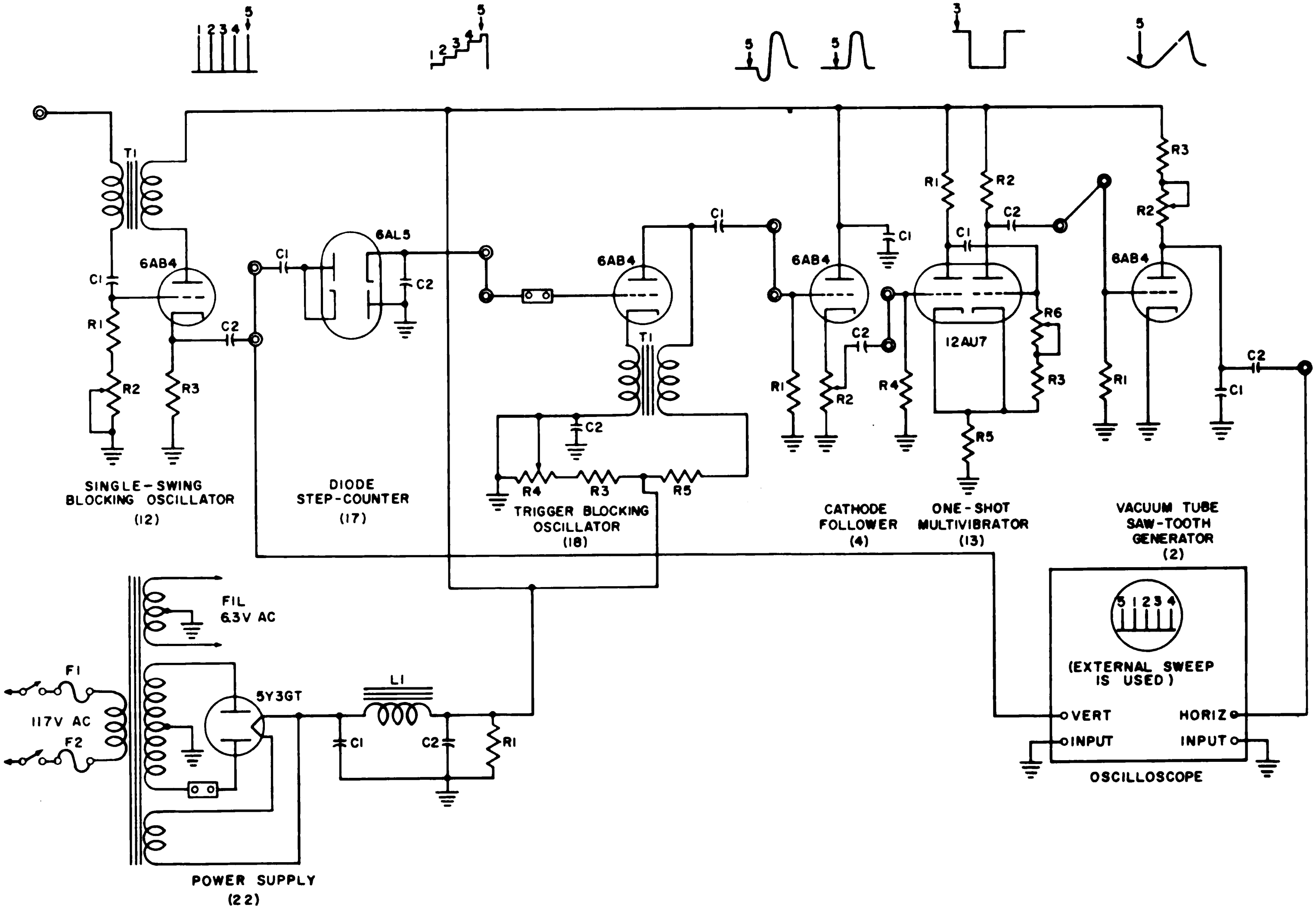
SECTION____

INDICATION (no output, distortion, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE EQUIPMENT.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)



Trouble-Shooting Diagram for Simplified Radar System
(Waveforms are taken from output of each stage.)

STUDENT TROUBLE-SHOOTING CHART
(To be designed by student.)

LABORATORY PLAN No. 36

SUBJECT

The multivibrator timer.

OBJECTIVE

To familiarize the students with the operation of the multivibrator timer chain, used as a master oscillator in a radar system.

MATERIAL REQUIRED

1. Square Wave Generator Chassis (1).
2. Cathode Follower Chassis (4).
3. Differentiator Chassis (7).
4. Parallel Diode Limiter Chassis (9).
5. Bias Supply Chassis (5).
6. Mixer Chassis (6).
7. Five-inch oscilloscope with leads.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.
10. Laboratory Chassis Mounting Rack.
11. Power Supply Chassis (22).

INTRODUCTION

A multivibrator timer is sometimes employed in radar equipment as the master oscillator in the timing chain. The major factor which favors the use of this type of timer is the circuit simplicity by which the required timing signal can be produced for the various components. Both positive- and negative-going rectangular pulses of equal and controllable width are produced simultaneously at the two plates of the multivibrator. It is possible, with such a timer, to perform the timing functions of the radar system with a minimum of additional timing circuits.

SUBJECT MATERIAL

1. Have the students connect the equipment and carefully check the waveforms obtained at the output of each stage of the timer chain.

2. Have the students make a careful observation of the waveforms that were taken, and supervise their construction of a synchrogram.

3. Insert troubles into the equipment, and have the students locate and remove the troubles, by the use of a procedure similar to that used in the previous EXPERIMENT.

4. Be sure to initial the students' work after each step is completed.

CONCLUSIONS

A multivibrator master oscillator is found frequently in the timer chain of a radar system. Its chief advantages over a blocking-oscillator timer are its simplicity and the ease with which it produces the required timing pulses. Also, less weight and space are required if the master oscillator is a multivibrator oscillator instead of a sine-wave oscillator. The saving results from the elimination of the wave-shaping circuits that are required to produce a square wave from a sine wave.

EXPERIMENT No. 36

SUBJECT

The multivibrator timer.

OBJECTIVE

To become familiar with the various types of waveforms that must be produced by a timer chain; to learn how these waveforms can be produced simply and dependably; and to gain experience in recognizing the common troubles peculiar to such a chain.

MATERIAL REQUIRED

1. Square Wave Generator Chassis (1).
2. Cathode Follower Chassis (4).
3. Differentiator Chassis (7).
4. Parallel Diode Limiter Chassis (9).
5. Bias Supply Chassis (5).
6. Mixer Chassis (6).
7. Five-inch oscilloscope with leads.
8. A-F oscillator with leads.
9. Vacuum-tube voltmeter with leads.
10. Laboratory Chassis Mounting Rack.
11. Power Supply Chassis (22).

INSTRUCTIONS

A radar system contains several chains, each performing a separate function. The timing of these chains must be extremely precise. Many of them must start or stop their generation of energy at exactly the same instant; others must be delayed for a definite number of microseconds; all are rigidly interdependent.

Such accuracy is made possible by the use of a master oscillator which is similar in principle to the one used in radio transmitters. The output of this master oscillator may be a train of sine waves, square waves, or narrow pips. In any case, the waveform must be converted into a variety of shapes, in order to trigger the various chains. A master oscillator and its associated wave-shaping circuits are called a "timer."

Several types of timers will be studied during this laboratory course. The Simplified Radar System, assembled in EXPERIMENT No. 35, employed a single-swing blocking oscillator as a master oscillator. The output frequency of the oscillator was "counted down" by a diode step counter and a triggered blocking oscillator. The amplitude was then limited and adjusted until it was suitable for triggering a one-shot multivibrator, which produced a negative gate pulse for actuating the sweep chain. At the same time, the master oscillator produced a series of narrow trigger pulses suitable for use directly as range markers.

In later EXPERIMENTS, studies will be made of a more elaborate timer using a single-swing blocking oscillator as a master oscillator, and of another system employing a sine-wave oscillator. The present EXPERIMENT will be devoted to the analysis of a timer in which a multivibrator is used as the master oscillator.

Inspection of the block diagram of figure 1 will show that a plate-coupled multivibrator (the Square Wave Generator Chassis (1)) delivers a positive square wave. The wave is passed through a cathode follower (4), and after being inverted is used as a gate for the sweep chain. Meanwhile, the positive-going wave of the master oscillator (1) passes through a cathode follower (6), and is used for unblanking the scope during the precise interval when the sweep voltage is moving the spot across the screen from left to right. The positive-going pulse is also passed through a differentiator (7), where it is converted into narrow positive and negative pips; the negative pips are removed by a parallel diode limiter (9), whose clipping level is adjusted by the bias supply (5). The accurately spaced positive pips produced by this network are used to trigger the marker chain, the range-notch chain, and the transmitter chain.

PROCEDURE

Construction of a Synchrogram

1. Connect the equipment as shown in the block diagram of figure 1. Connect the Mixer Chassis so that it will act as a cathode follower. Remove C1 from the circuit and insert SS1 ALT.

2. Connect the scope lead to the OUTPUT jack of the multivibrator (1). Measure the width of the positive pulses, in microseconds. At A in figure 2, draw the observed waveform, and record the results of your measurements.

3. Transfer the scope lead to the OUTPUT jack of the cathode follower (4). At B in figure 2, record the waveform and the time duration of the pulse observed at that point. This waveform could

be used as a gate, to actuate a sweep generator, after being inverted.

4. Connect the scope lead to the OUTPUT jack of the differentiator. At C in figure 2, record the waveform and the pulse widths observed at that point.

5. Connect the scope lead to the OUTPUT jack of the parallel diode limiter. Vary the positive bias control knob of the bias supply, and note the point at which all evidence of the negative pips disappear. Leave the knob at that setting. At D in figure 2, record the waveform and pulse width observed at that point. The sharp positive pips produced by this chain could be used to trigger the marker, range notch, and transmitter chains of a radar system.

6. Connect the scope lead to the OUTPUT jack of the cathode follower (6). Note that this cathode follower controls the amplitude of the square wave from the multivibrator, without inverting it. Vary the gain control, and note that the amplitude of the output waveform changes.

7. Set the gain control of the cathode follower at a point where the best output square wave is obtained. At E in figure 2, record the waveform and pulse width observed. This positive pulse could be used to unblank a radar scope during the time when the sweep is moving the spot across the screen.

Trouble Shooting

1. The instructor will insert troubles into your equipment.

Instructor's initials______

2. Locate and remove these troubles, using the same type of trouble-shooting procedure followed in EXPERIMENT No. 35. Keep an accurate set of notes, to assist you in trouble shooting the same chassis later in the course.

3. Fill out a JOB SHEET, and have the instructor check your work.

Instructor's initials______

4. If time permits, you may ask that further troubles be placed in your equipment, and may remove them for extra credit, filling out a second JOB SHEET.

Instructor's initials______

CONCLUSIONS

1. What two types of waveforms are generally used in timing the various chains of a radar system? Give several uses for each type.

a. Narrow pips: For triggering square-wave generators and transmitters, and for use as range markers.

b. Square waves: For gating vacuum-tube saw-tooth generators and shock-excited ringing oscillators, and for use as unblanking pulses and gate pulses.

2. Name one advantage that the multivibrator type of master oscillator has over the blocking-oscillator type.

The simplicity of the multivibrator is its chief advantage over the blocking oscillator. It has a controllable pulse width, and either positive or negative pulses are obtainable, thus permitting the timing function of the radar system to be performed with a minimum of additional timing circuits. Also, the multivibrator produces square waves directly, while the blocking oscillator does not.

3. What would be the effect upon the scope pattern if a plate-loaded R-C amplifier were used in the unblanking chain, instead of the cathode follower used in that position. Explain, drawing the necessary synchrogram.

The output, when employing the plate-loaded R-C amplifier, would be 180° out of phase with that of the cathode follower. Hence, the scope would blank during the rise time of the saw-tooth generator, and show a trace during the decay time.

4. Give a detailed step-by-step procedure to locate the trouble when there is no unblanking gate, but the sweep gate and the three triggers are normal.

a. Check the input to the cathode follower from which the unblanking pulse is obtained, using a scope.

b. If the input is normal, make voltage measurements and resistance checks, to locate the faulty component in the cathode follower.

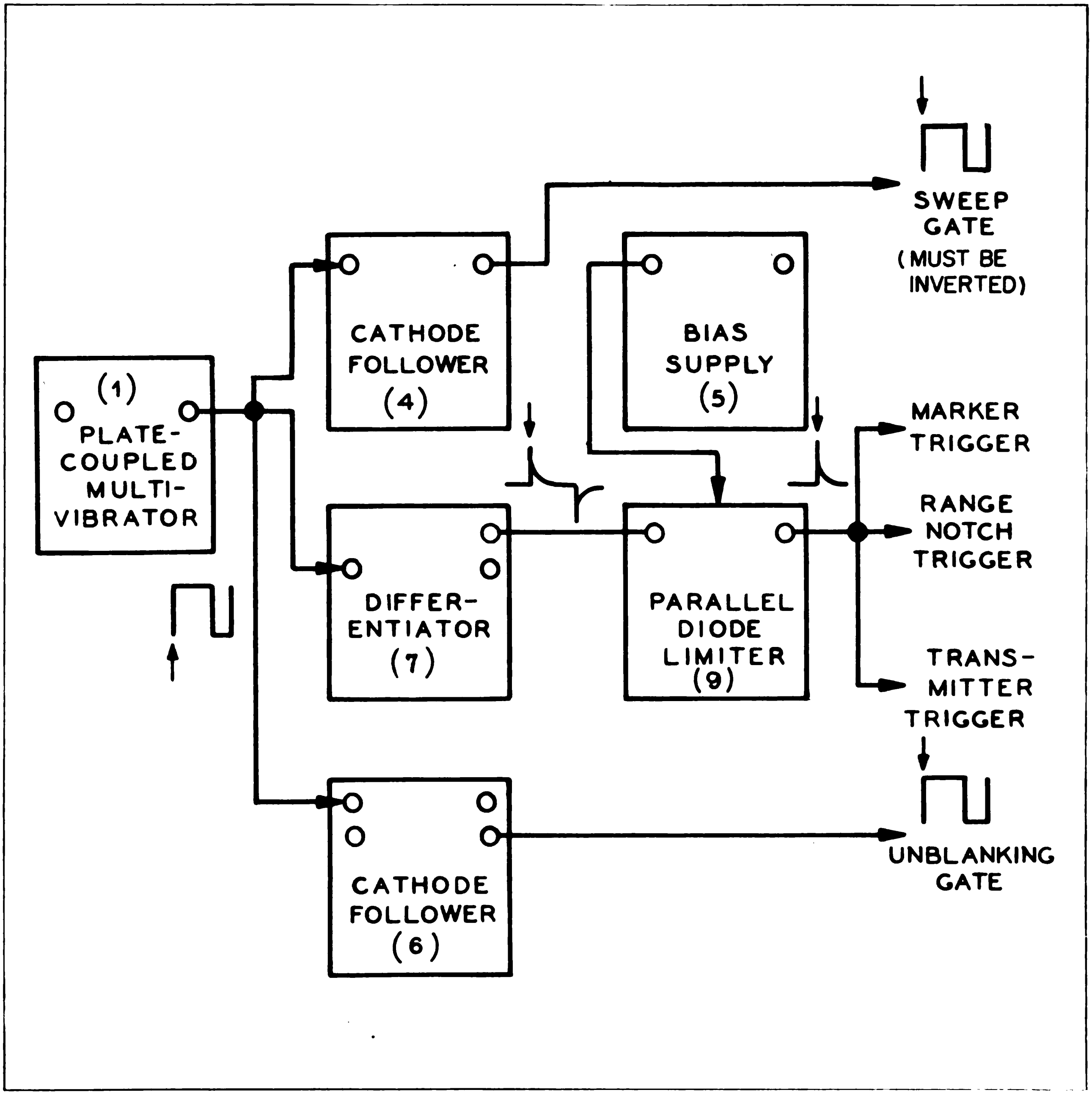


Figure 1. Block Diagram of a Timer Using a Multivibrator as a Master Oscillator

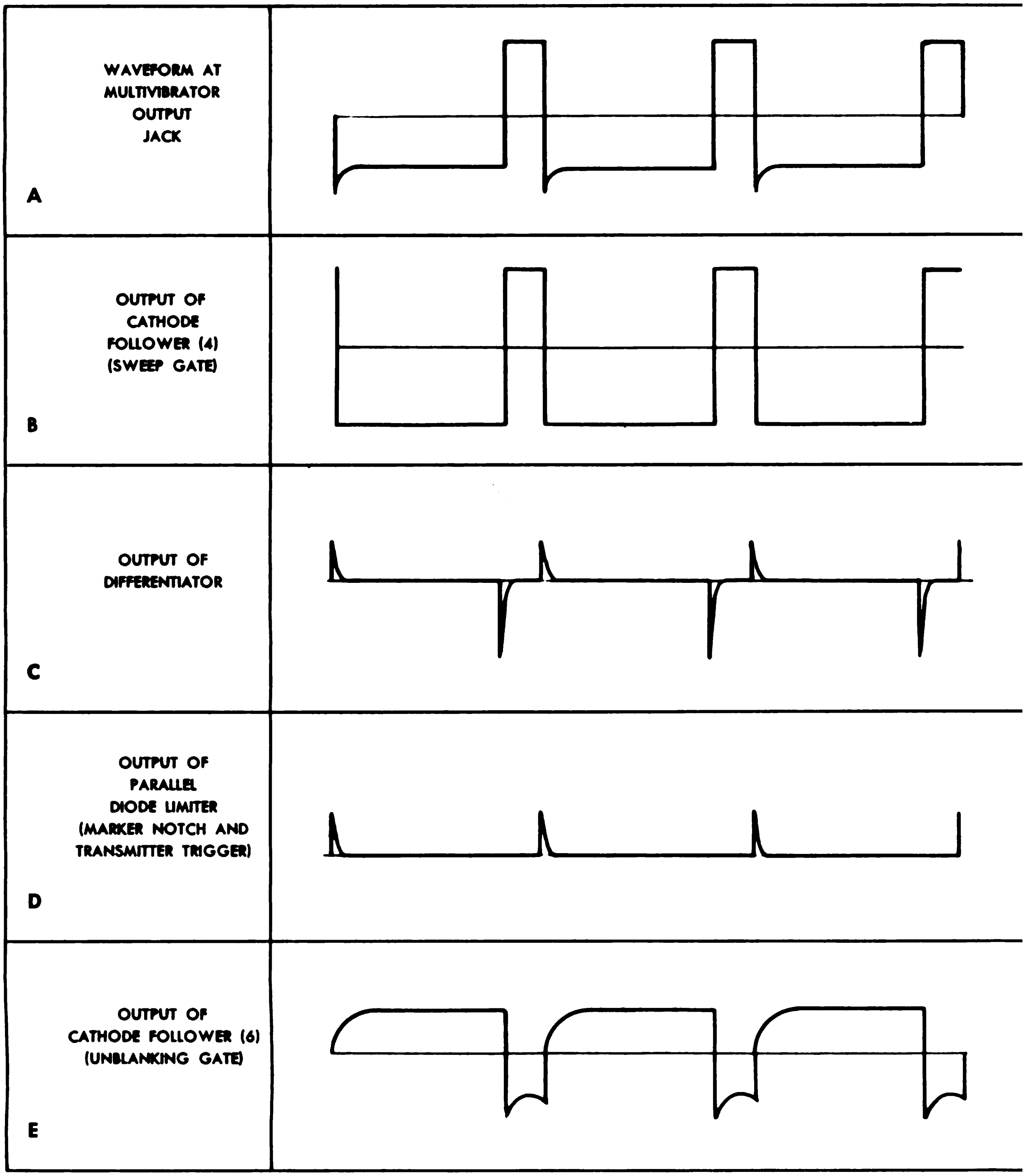

WAVEFORM AT MULTIVIBRATOR OUTPUT JACK
A
OUTPUT OF CATHODE FOLLOWER (4) (SWEEP GATE)
B
OUTPUT OF DIFFERENTIATOR
C
OUTPUT OF PARALLEL DIODE LIMITER (MARKER NOTCH AND TRANSMITTER TRIGGER)
D
OUTPUT OF CATHODE FOLLOWER (6) (UNBLANKING GATE)
E

Figure 2. Synchrogram of Waveforms Developed in a Timer Using a Multivibrator as a Master Oscillato

JOB SHEET

STUDENT'S NAME______________________________________

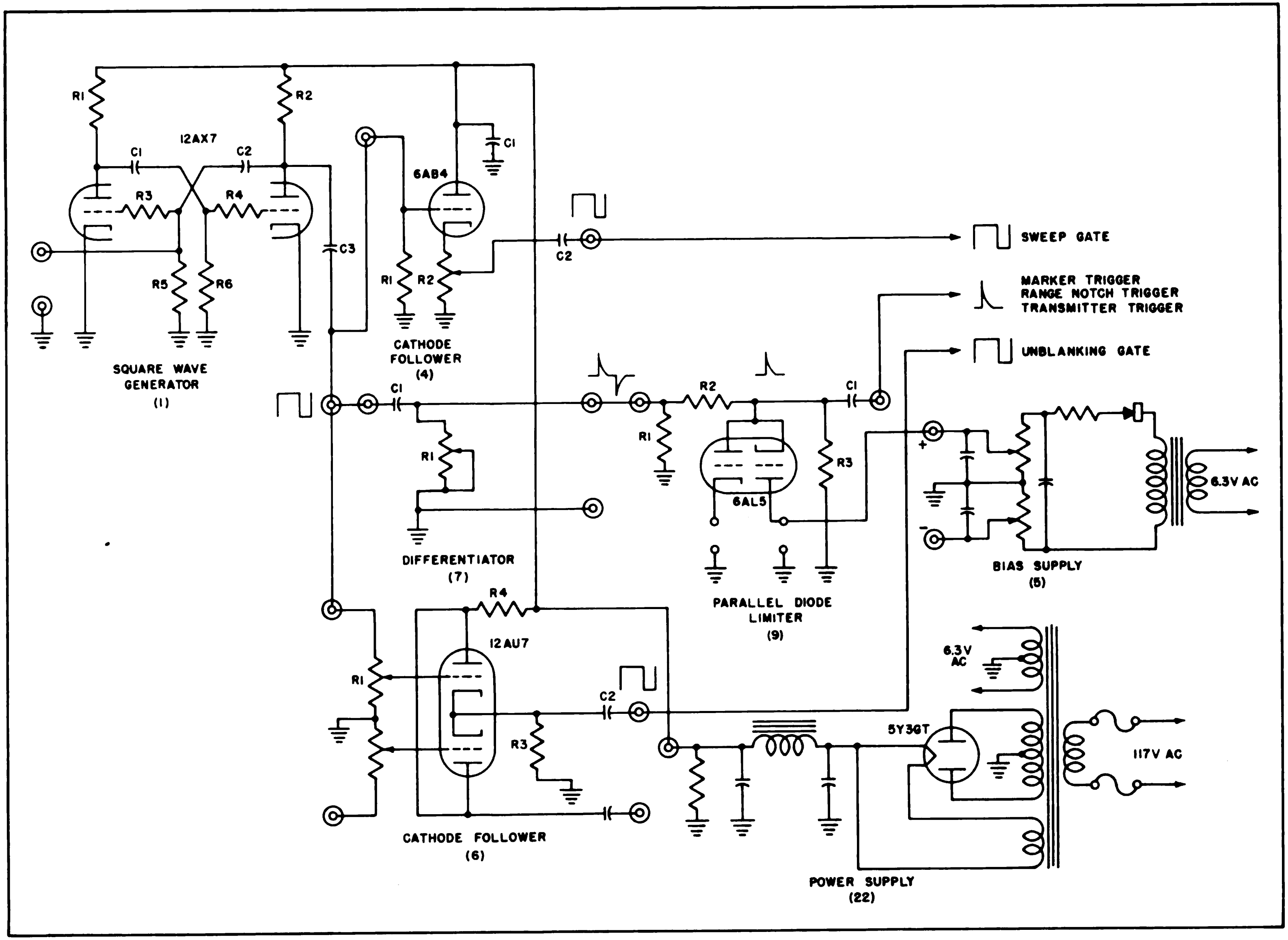
SECTION____

INDICATION (no output, distortion, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE EQUIPMENT.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)



Trouble-Shooting Diagram for Multivibrator Timer
(Waveforms are taken from output of each stage.)

STUDENT TROUBLE-SHOOTING CHART
(To be designed by student.)

LABORATORY PLAN No. 37

SUBJECT

The blocking oscillator timer.

OBJECTIVE

To have the student analyze the blocking-oscillator timer circuit, and study the operation and the frequencies, waveforms and amplitude of the timer output; to help them gain experience in trouble shooting this chain.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Cathode Follower Chassis (4).
3. One-Shot Multivibrator Chassis (13).
4. Mixer Chassis (6).
5. Triode Limiter Chassis (10).
6. Five-inch oscilloscope with leads.
7. Vacuum-tube voltmeter with leads.
8. A-F oscillator with leads.
9. Laboratory Chassis Mounting Rack.
10. Power Supply Chassis (22).

INTRODUCTION

The blocking-oscillator timer circuit plays an important part in setting the timer reference in a radar set. The function of the timer chain is to insure that all circuits connected with the radar system operate in a definite time relationship with each other, and that the interval between pulses is of the proper length.

There are two practical methods used in setting the timing requirement in radar systems.

1. Timing by a separate unit.

The repetition frequency of the pulses can be determined by an oscillator of any stable type, such as a sine-wave oscillator, a multivibrator, or the blocking oscillator which is used in this EXPERIMENT.

2. Timing within the transmitter.

The transmitter may establish its own pulse width and pulse repetition frequency and provide synchronizing pulses for the other components of the system. This is accomplished by associated circuits, such as a self-pulsing or blocking r-f oscillator with properly chosen circuit components. This method of timing eliminates a number of special timing circuits.

SUBJECT MATERIAL

1. Have the students connect the equipment as shown in the block diagram in this EXPERIMENT; they should make the necessary connections and adjustments as prescribed in the EXPERIMENT.

2. Have the students carefully observe the waveforms that are obtained; supervise them in the construction of a synchrogram.

3. A trouble-shooting procedure will be made up by the students in the trouble-shooting part of this EXPERIMENT.

4. Inspect and initial the student's work as called for in the EXPERIMENT. Keep a constant bench-to-bench check on the students' technique and procedure.

CONCLUSIONS

The blocking-oscillator timer is the unit which controls and synchronizes the operation of the various components of many radar systems. The blocking-oscillator timer employed in this EXPERIMENT will be known as the master oscillator, the name which is used in most radar sets. This oscillator will establish the repetition rate, and will supply trigger voltages for controlling the entire radar system.

EXPERIMENT No. 37

SUBJECT

The blocking-oscillator timer.

OBJECTIVE

To study the circuit operation and the output frequencies, waveforms, and amplitudes of the timer to be used in all future EXPERIMENTS; to gain experience in trouble shooting this chain.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Cathode Follower Chassis (4).
3. One-Shot Multivibrator Chassis (13).
4. Mixer Chassis (6).
5. Triode Limiter Chassis (10).
6. Five-inch oscilloscope with leads.
7. Vacuum-tube voltmeter with leads.
8. A-F oscillator with leads.
9. Laboratory Chassis Mounting Rack.
10. Power Supply Chassis (22).

INSTRUCTIONS

The timer to be studied in this EXPERIMENT will be used throughout the course as standard equipment for applying any timing pulses that may be required. Its operation is as follows:

The master oscillator is a single-swing blocking oscillator (12), whose cathode circuit delivers narrow positive pulses.

Since it must trigger a one-shot multivibrator (13) having somewhat critical trigger-amplitude requirements, a cathode follower is inserted between the master oscillator and the multivibrator. The purpose of this cathode follower is to attenuate the trigger pulse to a point where it will not overdrive the multivibrator and produce a distorted waveform.

The one-shot multivibrator (13) produces a negative gate pulse to drive the sweep chain. By using different resistors for grid lead, R6, the width of the gate (and, consequently, the duration of the saw-tooth sweep) can be varied at will.

The positive-going gate appearing at OUTPUT No. 2 jack of the multivibrator passes through a two-stage inverter-amplifier (6 and 10), and emerges as a positive-going square wave of adjustable amplitude. This pulse is used to unblank the scope during the time interval when the spot is moving forward across the screen. Its amplitude must be adjustable, so that exactly the proper degree of unblanking can be obtained.

Three other trigger pulses are taken directly from the output of the cathode follower (4). These positive pips are employed to trigger the range-notch chain, the marker chain, and the transmitter.

The student is urged to make a complete set of notes on the voltages, frequencies, and waveforms developed in this timer. Since the chain will be used in every EXPERIMENT during the remainder of the course, a thorough familiarity with its characteristics will save time that might otherwise have to be devoted to trouble shooting.

PROCEDURE

Connection and Adjustment

1. In the single-swing blocking oscillator, remove shorting strip, SS-1, and insert a 100,000-ohm resistor in its place. Put SS-2 in normal position.
2. In the one-shot multivibrator, place SS-1 in normal.
3. In the Triode Limiter Chassis (10), remove the 100,000-ohm resistor from R2, and replace it with a shorting strip. This eliminates the grid-limiting action of the stage, and converts the stage for use as a conventional R-C amplifier.
4. Change the Mixer Chassis (6) for use as an inverter amplifier. Insert shorting strips in SS-1 and SS-2 alternate.
5. Connect the equipment as shown in the block diagram of figure 1.
6. Check with a scope, at the points indicated in figure 1, to make sure that the two gates and three triggers are being generated. If they do not appear, locate and remove the trouble before proceeding.

Construction of a Synchrogram

1. Connect the scope lead to the OUTPUT jack of the single-swing blocking oscillator. Adjust the oscillator to a frequency of about 60 cycles per second. At A in figure 2, record the resulting waveform and its amplitude.
2. Transfer the scope lead to the OUTPUT jack of the cathode follower (4). At B in figure 2, record the waveform and amplitude observed. Be careful to place it (and all subsequent waveforms)

in the proper phase relationship. This pulse could be used to trigger the range-notch, marker, and transmitter chains. Refer to figure 1.

3. Connect the scope to the top OUTPUT jack of the one-shot multivibrator. Turn the multivibrator potentiometer knob to obtain the widest possible positive gate. At C in figure 2, record the waveform and amplitude of the gate. On the drawing, indicate the width of the positive and negative pulses of each gate, in microseconds. This waveform is used to control the sweep generator.

4. Connect the scope lead to bottom OUTPUT jack of the one-shot multivibrator (13). At D in figure 2, record this waveform, together with its amplitude and the width of its positive and negative pulses.

5. Connect the scope lead to the OUTPUT jack of the first inverter-amplifier stage (6). Vary the gain control of the amplifier over its entire range, and look for signs of distortion. Describe any symptoms of distortion you observe, and explain why they occur.

6. Adjust the amplifier gain control to produce the best possible square wave. At E in figure 2, record this waveform, together with its amplitude and the width of its negative and positive pulses.

7. Connect the scope lead to the OUTPUT jack of the second amplifier stage (10). Adjust the bias potentiometer of chassis No. 10 to produce the best possible square wave. At F in figure 2, record the waveform, amplitude, and pulse widths. This waveform is used as an unblocking gate for the radar scope.

Trouble Shooting

1. The instructor will now insert troubles into your equipment.

Instructor's initials______

2. Locate and remove these troubles, using the same type of trouble-shooting procedure followed in previous EXPERIMENTS. Keep an accurate set of notes, to assist you in drawing up a trouble-shooting procedure for the timer, as required under CONCLUSIONS.

This timer is the first of four chains that will be studied individually, and will later be combined into the Advanced Radar System. As each chain is studied, a complete trouble-shooting chart for that chain will be prepared by the student. This chart will cover the procedure necessary to isolate the troubles to one particular chassis of the chain (or to one small group of chassis, such as a two-stage inverter-amplifier), and to locate the defective part or improper adjustment. Therefore, include in your chart all necessary Key and Secondary Test Points. The Major Test Points will be assigned later, when the entire system is assembled.

3. Fill out a JOB SHEET, and have the instructor check your work.

Instructor's initials______

4. If time permits, you may ask that further troubles be placed in your equipment, and may remove them for extra credit, filling out a second JOB SHEET.

Instructor's initials______

CONCLUSIONS

1. From your notes, prepare a complete trouble-shooting chart and trouble-shooting schematic diagram for the timer. Proceed as described in step 2 under Trouble Shooting. Lay out your work in columns, as was done previously for similar equipments that you have already studied.

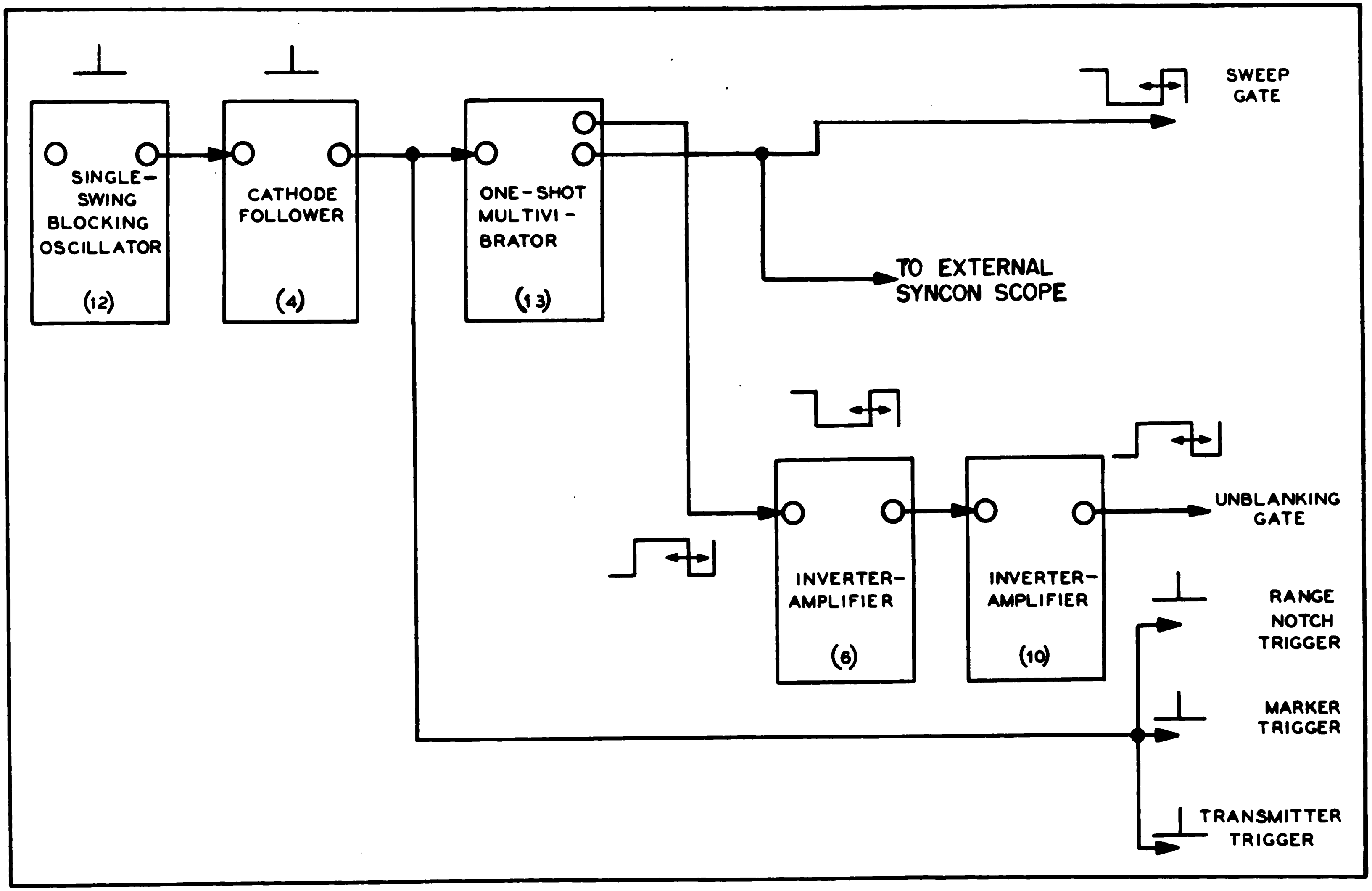


Figure 1. Block Diagram of Blocking-Oscillator Timer

A OUTPUT OF SINGLE-SWING BLOCKING OSCILLATOR (MASTER OSCILLATOR)	
B OUTPUT OF CATHODE FOLLOWER (TRIGGER PULSES)	
C POSITIVE WAVEFORM AT TOP OUTPUT OF MULTIVIBRATOR (SWEEP GATE)	POSITIVE PULSE NEGATIVE PULSE
D NEGATIVE WAVEFORM AT BOTTOM OUTPUT OF MULTIVIBRATOR	
E OUTPUT OF FIRST INVERTER-AMPLIFIER	
F OUTPUT OF SECOND INVERTER-AMPLIFIER (UNBLANKING GATE)	

Figure 2. Synchrogram of Waveforms Developed in Blocking-Oscillator Timer

JOB SHEET

STUDENT'S NAME____

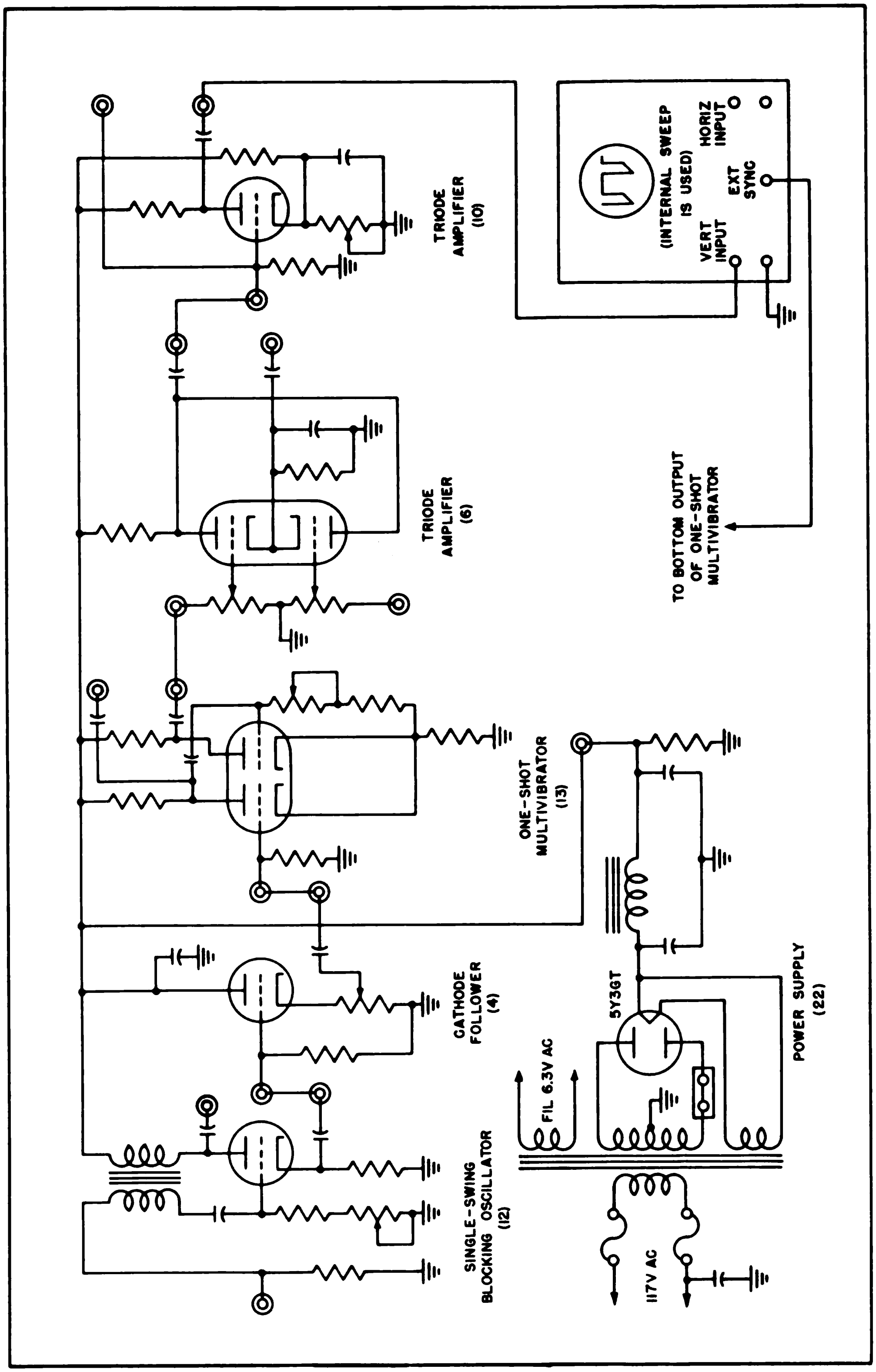
SECTION____

INDICATION (no output, distortion, hum, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE WAVE-SHAPING CHAIN.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)



Trouble-Shooting Diagram for Blocking-Oscillator Timer

STUDENT TROUBLE-SHOOTING CHART

(To be designed by student.)

LABORATORY PLAN No. 38

SUBJECT

The "A" scope sweep chain.

OBJECTIVE

To teach the students the circuit operation of an "A" scope sweep chain, and to have them observe the various types of waveforms that are produced by this type of radar system.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Cathode Follower Chassis (4).
3. One-Shot Multivibrator Chassis (13).
4. Mixer Chassis (6) (2 required).
5. Triode Limiter Chassis (10).
6. Vacuum-Tube Saw-tooth Generator Chassis (2).
7. Diode Clamper Chassis (11).
8. Bias Supply Chassis (5).
9. Five-inch oscilloscope with leads.
10. A-F oscillator with leads.
11. Vacuum-tube voltmeter with leads.
12. Laboratory Chassis Mounting Rack.
13. Power Supply Chassis (22).
14. Audio Voltage Amplifier (27).

REFERENCES

Laboratory notes on EXPERIMENTS covering the vacuum-tube saw-tooth generator and the diode clamper.

INTRODUCTION

The chain of chassis connected in this EXPERIMENT is capable of functioning as a basic "A" scope sweep system. This type of radar system contains a timer chain and a sweep chain.

The "A" scan system uses an electrostatic cathode-ray tube, with a linear sweep applied to the horizontal deflection plates to establish a time base, and range-marker pulses applied to the vertical plates. Since the sweep is linear with time, a scale which is calibrated in range may be placed on the scope screen. By finding the time in microseconds between pulses, it is possible to determine how far the target is from the radar antenna. Unblanking pulses are also supplied in this system, so that only the forward sweep of the saw-tooth waveform being applied to the horizontal-deflection plates will be visible on the scope screen.

SUBJECT MATERIAL

1. Make sure that the equipment shown in the diagram is connected properly. The students should make the necessary connections and adjustments, as prescribed in the EXPERIMENT.
2. The students should make drawings of the waveforms obtained. Supervise the construction of a synchrogram.
3. Inspect and initial the students' work as called for in the EXPERIMENT. Keep a constant bench-to-bench check on the students' technique and procedure.
4. Check to see if the students are answering the questions that are in the PROCEDURE and CONCLUSIONS of this EXPERIMENT.

CONCLUSIONS

The "A" scan presentation used in this EXPERIMENT employs a cathode-ray tube which presents data on the range of a target. The horizontal distance across the screen from the transmitted pulse to the received pulse indicates the distance to the target.

EXPERIMENT No. 38

SUBJECT

The "A" scope sweep chain.

OBJECTIVE

To study the circuit operation of a typical sweep chain for use with an "A" scope, and to study the waveforms produced by this chain.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Cathode Follower Chassis (4).
3. One-Shot Multivibrator Chassis (13).
4. Mixer Chassis (6).
5. Triode Limiter Chassis (10).
6. Vacuum-Tube Saw-tooth Generator Chassis (2).
7. Diode Clamper Chassis (11).
8. Bias Supply Chassis (5).
9. Five-inch oscilloscope with leads.
10. A-F oscillator with leads.
11. Vacuum-tube voltmeter with leads.
12. Laboratory Chassis Mounting Rack.
13. Power Supply Chassis (22).
14. Audio Voltage Amplifier (27).

INSTRUCTIONS

The group of chassis shown in the sweep-chain block of figure 1 provides a saw-tooth voltage suitable for moving the spot horizontally across the scope screen at a nearly linear rate, then returning it very quickly to the starting point.

The sweep chain is driven by a negative gate pulse provided by the timer. For the duration of the negative gate, the vacuum-tube saw-tooth generator (2) produces an output voltage that rises almost linearly with time. At the end of the negative gate, the output voltage of the saw-tooth generator falls very quickly to zero.

The resulting saw-tooth voltage is passed through an inverter-amplifier (6). Without the inverter-amplifier, the scope trace would move from right to left across the scope, resulting in an improper presentation if you have a scope with direct connection terminals at the back. If you have not, the diode clamper part of the experiment cannot be performed. The use of Chassis (27), as a plate-loaded inverter-amplifier, also makes it possible to control the length of the trace upon the screen.

The negative-going saw-tooth waveform is then applied to a diode clamper (11) whose clamping point is adjustable by means of the bias-supply unit (5). When the bias is set at zero, the sweep will start at the center of the screen and move toward the right-hand side. When the bias is set at any positive value, the sweep will start at some point to the left of center, and will move to the right. The clamping circuit improves over-all stability, and reduces any tendency toward "jitter."

In order to eliminate confusing back traces, the grid of the cathode-ray tube is normally held at a negative potential of sufficient amplitude to prevent the appearance of a visible trace. During the forward sweep, however, this negative voltage is counteracted by the appearance of a positive "unblanking gate." This gate, produced by shaping circuits in the timer, exactly coincides in time with the negative sweep gate, and allows the scope trace to be visible during its forward stroke only. Fine adjustment of the unblanking-gate amplitude is necessary, in order to eliminate the portions of the trace that are undesirable, without also eliminating part of the desired trace. Provision for this adjustment is made by the use of a variable-gain amplifier (6) in the timer chain.

PROCEDURE

Connection and Testing

1. Set up the timer chain as described in EXPERIMENT No. 37. Make sure that it is operating at the frequency and with the amplitudes and waveforms that have been determined to be correct.

2. Place SS-1 in normal position in bias supply. In the vacuum-tube saw-tooth generator, remove the .01-μf. capacitor normally used at C1 (the charging capacitor), and replace it with a .1-μf. capacitor.

3. Connect the AF Voltage Amplifier Chassis (27) for use as a plate-loaded R-C amplifier. Use a .1 μf capacitor for C2.

4. Connect the equipment as shown in the block diagram of figure 1. Do not, at this time, connect the lead to the intensity-modulation post of the scope, nor the direct lead to the horizontal-deflection plates. Turn the sweep-selector switch of the scope to internal sweep, and use the in-

strument in the usual manner until near the end of the EXPERIMENT, when the output of the sweep chain will be substituted for the internally generated saw-tooth of the scope.

5. Connect the vertical lead of the scope to the OUTPUT jack of the vacuum-tube saw-tooth generator. Observe that a positive-going saw-tooth waveform of moderate linearity is produced.

6. Connect the vertical scope lead to the OUTPUT jack of the inverter-amplifier (27), and note that a negative-going saw-tooth waveform appears on the screen. Rotate the gain-control knob of the sweep-chain inverter-amplifier (6), and inspect the output waveform for signs of distortion. Set the knob at the point which will deliver maximum output voltage without distortion.

7. Transfer the scope lead to the OUTPUT jack of the diode clamper. Observe that the waveform appearing there is a negative-going saw-tooth similar to the one observed at the output of the inverter-amplifier. Make slight adjustments of the gain-control knob of the inverter-amplifier, and make sure that maximum output from the clamper is being obtained without distortion. Rotate the *positive-bias* control knob of the bias supply (5), and look for any distortion or hum that may be injected into the circuit by this chassis. If hum appears, determine its cause, and remove the trouble before proceeding.

Construction of a Synchrogram

1. Refer to figure 2. In the spaces provided, record the indicated waveforms, being careful to place them in proper phase relationship with each other.

2. Make careful measurements of the voltage amplitude and the pulse widths, in microseconds, of each waveform, and enter these figures on your drawing.

Unblanking

1. Connect the vertical scope lead to the OUTPUT jack of the saw-tooth generator. Adjust the scope to present three cycles of the saw-tooth waveform.

2. Connect a lead between the OUTPUT jack of the second inverter-amplifier (10) in the timer chain and the intensity-modulation binding post of the scope.

3. Turn the gain-control knob of the first inverter-amplifier stage (6) in the timer chain to its zero-output position. Observe the trace appearing on the screen. The trace should take the form of a moderately linear saw-tooth with a plainly visible back trace.

4. Now slowly advance the gain-control knob of the timer-chain inverter-amplifier. Note that the back trace becomes fainter, and finally disappears entirely. Make fine adjustments of the gain-control knob until nothing remains but the forward trace of the saw-tooth waveform. Note the setting of the inverter-amplifier. This will be used later, in resetting the circuit to produce proper blanking. Turn the gain control knob fully clockwise; observe and explain the results.

With the gain control set fully counter-clockwise (zero output), there is no blanking action, and both trace and retrace appear on the screen. As the gain control is turned clockwise (increasing the amplitude of the unblanking gate), the retrace is eliminated. With maximum unblanking voltage applied, the retrace is completely eliminated and the forward trace is bright and defocused. In some cases, the unblanking voltage may be so great as to cause the grid of the scope to draw current. When this happens, part of the forward trace is also eliminated.

5. Repeat these adjustments several times, until you are thoroughly familiar with the changes that occur as the gain-control knob is turned.

6. Vary the setting of the gate-width control (grid-leak potentiometer R6 of the one-shot multivibrator). Does variation of the gate width affect the completeness of blanking? Is it necessary to make any readjustment of the unblanking control (gain control of the inverter-amplifier) when the gate width is changed? Explain fully.

Varying the gate width varies the amplitude, necessitating readjustment of the gain-control to maintain proper unblanking. This is true because varying the grid-leak resistor varies the amplitude, as well as the duration of the voltage applied to the grid.

Use of the Sweep-Chain Waveform on the Horizontal Plates

1. Remove the vertical lead from the scope. Connect a lead from the horizontal-input binding post, on the front of the scope, to the OUTPUT jack of the vacuum-tube saw-tooth generator.

2. Turn the frequency-selector switch of the scope to the position which disables the scope's internal saw-tooth generator. The horizontal-deflection plates are now receiving their sweep voltage from the saw-tooth generator in the sweep chain, after it has passed through the scope's horizontal amplifier.

3. Adjust the horizontal-gain control of the scope until the horizontal trace fills nearly all the

width of the screen. The trace should be a narrow line, without vertical deflection (since the vertical input lead is disconnected). Set the knob of the inverter-amplifier to the pencil mark drawn previously. This applies the correct amount of blanking voltage.

4. Study this line carefully, noting that it is of nearly uniform brilliance throughout its length.

5. Turn the inverter-amplifier knob fully counterclockwise, thus removing all blanking from the circuit. Note the appearance of the trace. Explain the cause of the bright portion, at the left-hand end of the trace. Vary the width of the sweep generator gate, and not the effect upon the bright portion of the trace. Explain the results.

With no blanking applied, both trace and retrace appear on the screen. The bright portion on the left-hand end of the trace is caused by the slowness of the retrace at that point. Increasing the sweep-gate width speeds up the retrace, therefore eliminating the bright portion appearing on the left-hand end of the trace.

6. Vary the unblanking-gate control knob back and forth, noting the changing appearance of the scope trace. Finally, return the knob to the setting where its pointer is opposite the pencil mark that indicates the proper degree of unblanking.

Clamping

1. Move the horizontal scope lead to the OUTPUT jack of the diode clamper. Disconnect the other end of the lead from the horizontal-input binding post of the scope, and connect it directly to one of the horizontal plates. The instructor will show you how this is accomplished on the particular scope you are using.

2. Set the positive bias control knob of the bias supply (5) for zero bias.

3. Adjust the gain-control knob of the inverter-amplifier (27) in the sweep chain to produce a trace of suitable length, without bright spots that would indicate distortion. At A in figure 3, record the position of the trace on the screen.

4. Turn the positive voltage control knob of the bias supply fully clockwise, so as to produce maximum positive bias on the plate of the clamper tube. At B in figure 3, record the position of the trace on the screen. Measure and record the positive bias necessary to move the trace to that position.

5. Move the bias-control knob back and forth, and observe the movements of the scope trace. Describe them in the space provided below, and explain fully why they occur.

When the bias control is set for zero bias, the trace starts at the center of the screen and extends to the right. As the bias control is turned in a clockwise direction (making the bias positive), the trace moves to the left, without changing its length. The bias determines the positive potential on the cathode of the clamping diode, fixing the voltage level from which the saw-tooth rises and, therefore, the position of the trace on the screen.

Presentation of Vertical Traces

1. Reconnect the lead to the vertical-input binding post of the scope. Connect the other end of this lead to the output of the a-f oscillator. Adjust the oscillator to a frequency of approximately 1000 cycles, and make fine adjustments in its tuning until a stationary group of five sine waves appears on the screen.

2. Note that the sync controls of the scope have no effect upon the trace, and that it must be held stationary by fine adjustment of the a-f oscillator controls. Explain why this is true.

The sync control of the scope has no effect on the trace because the sweep comes from an external source, and is applied directly to the deflection plates. The sync voltage is applied to the internal sweep generator, which is inoperative in this setup.

3. Disconnect the vertical lead of the scope from the a-f oscillator, and connect it to the OUTPUT jack of the single-swing blocking oscillator in the timer chain. Describe the trace observed on the screen. If a trigger pulse appears on the screen, explain why it occupies the position it does. If no pulse can be observed, explain why. Explain further why there can be any doubt as to whether a trigger pulse will appear on the trace.

The trigger pulse appears at the extreme left-hand end (start) of the sweep trace. This is because the trigger pulse drives the output (gate) of the multivibrator negative. This gate, when applied to the saw-tooth generator, causes the sweep (saw-tooth) voltage to start forming. The trigger pulse, then, coincides with the leading edge of both the gate and the sweep.

If no pulse is observed, it may be assumed that there is a finite time lag between the trigger pulse and the start of the trace across the screen, and that, in this particular case, the trigger pulse is arriving at the scope before the unblanking saw-tooth starts its sweep. Removing the unblanking gate will permit the pulse to become visible at the end of the retrace (left-hand end of the sweep).

CONCLUSIONS

1. Explain in detail how the retrace is removed from the scope when using the equipment studied in this EXPERIMENT.

The bottom or negative OUTPUT of the one-shot multivibrator gates the vacuum-tube saw-tooth generator. The positive OUTPUT is applied, after amplification, to the grid of the cathode-ray tube. Therefore, when the saw-tooth generator is charging, the voltage on the grid of the cathode-ray tube is such that the tube conducts. When the saw-tooth generator is discharging and resting, there is a high negative voltage on the grid of the cathode-ray tube, cutting it off.

2. What would be the result of using too much unblanking voltage? Of using too little unblanking voltage? Explain.

Too much unblanking voltage would cause the scope to conduct too heavily during trace time, resulting in a bright, blurred, and shortened forward sweep. Too little unblanking voltage, on the other hand, would fail to drive the grid below cutoff during decay of the saw-tooth voltage, permitting the retrace, as well as the trace, to appear on the screen.

3. How would you determine accurately the proper setting of the unblanking-gate amplitude control?

a. Feed the saw-tooth to the horizontal plates of the scope.

b. Feed a sine wave from the A-F oscillator to the vertical plates.

c. Adjust the amplitude of unblanking gate until a complete sine wave, with no retrace, appears on the screen.

4. Explain why a diode clamper is desirable in this sweep chain, and how it accomplishes its purpose.

The diode clamper permits positioning of the start of the sweep trace, and minimizes jitter. This action is the result of clamping the start of the sweep to some positive reference (bias) value.

5. Name several ways in which the linearity of the sweep chain could be improved. Discuss the practical limitations of each method that would prevent perfect linearity from being realized.

a. Increase the value of the charging capacitor in the saw-tooth generator. Such a substitution however, results in a decrease in amplitude of the saw-tooth voltage, and this consideration prevents carrying the substitution through until perfect linearity is realized.

b. Increase the resistance between the capacitor and B— (charge path of the capacitor). The limitations given above also apply here.

c. Decrease the width of the negative gate. This shortens the sweep, however, thus the amount of information that may be superimposed on the trace.

d. Adjust the amplifier for better frequency response by increasing the value of coupling capacitors, etc. Beyond a certain point, however, no further improvements are observable.

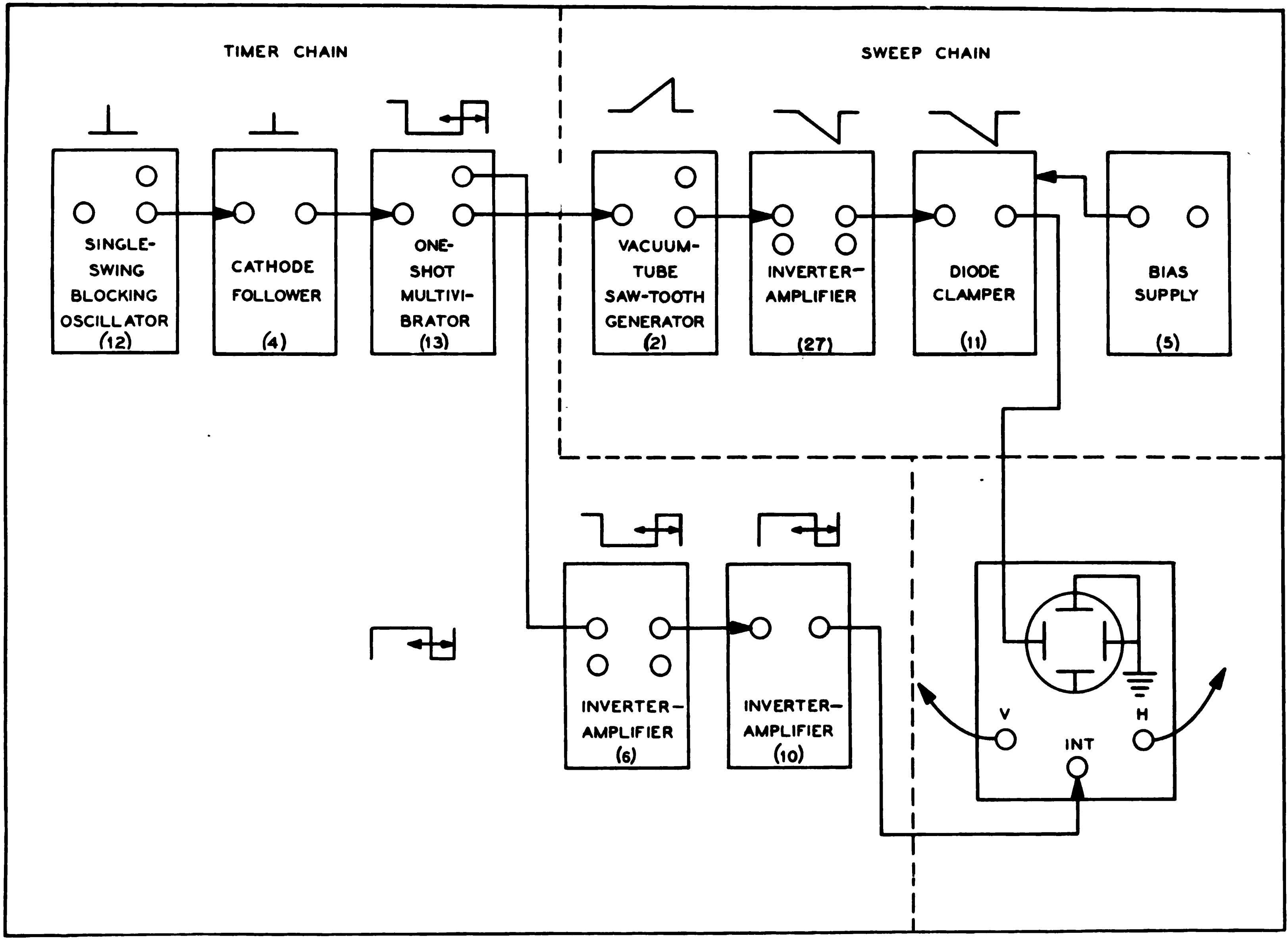


Figure 1. Block Diagram of "A" Scope Sweep Chain, Driven by Blocking-Oscillator Timer

A SWEEP GATE (BOTTOM OUTPUT OF ONE-SHOT MULTIVIBRATOR)	
B OUTPUT OF SWEEP GENERATOR	
C OUTPUT OF SWEEP INVERTER-AMPLIFIER	
D OUTPUT OF SWEEP CLAMPER (HORIZONTAL SWEEP)	
E UNBLANKING GATE	

Figure 2. Synchrogram of Waveforms Appearing in "A" Scope Sweep Chain

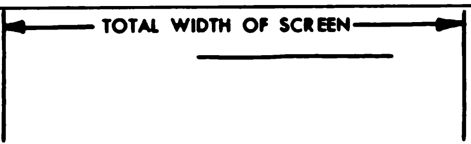
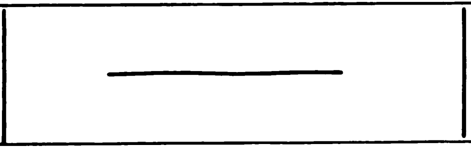
A POSITION OF SWEEP WHEN CLAMPED AT ZERO	
B POSITION OF SWEEP WHEN CLAMPED AT__________VOLTS POSITIVE	

Figure 3. Effect of Clamper Bias Voltage upon Sweep-Trace Position

LABORATORY PLAN No. 39

SUBJECT

Trouble shooting the "A" scope sweep chain.

OBJECTIVE

To familiarize the students with the proper method of trouble shooting an "A" scope sweep chain; to develop a trouble-shooting chart and schematic diagram of the sweep chain.

MATERIAL REQUIRED

Same as in EXPERIMENT No. 38.

INTRODUCTION

This EXPERIMENT will be aimed at developing in the student an ability to work out for himself a common-sense method of localizing trouble to one unit of this equipment, isolating the difficulty to one particular circuit, and locating the defective part or the improper adjustment. The quickest way for the student to develop such a faculty is to draw up sample procedures on equipment with which he is already thoroughly familiar, such as the laboratory chassis with which he has been working. This method will be followed, and the student will receive credit not only for the speed with which he can eliminate troubles, but for the systematic method by which he conducts his trouble shooting.

SUBJECT MATERIAL

1. Before they come to the laboratory, have the students draw up a trouble-shooting procedure suitable for locating troubles in the "A" scope sweep chain.

2. Have the students set up the "A" scope sweep chain, as studied in EXPERIMENT No. 38. When the sweep chain is working properly, insert troubles into the system.

3. Have the students follow the trouble-shooting procedure which they devised for this EXPERIMENT.

4. Check to see that they are filling out the attached JOB SHEETS, giving full details of the symptoms observed, the procedure followed, the results obtained, and the trouble found.

5. Initial the students' JOB SHEETS, as suggested in the EXPERIMENT.

CONCLUSIONS

The experience gained in this and other EXPERIMENTS in the application of the "Localize, Isolate, Locate" trouble-shooting method should enable the students to deal quickly with maintenance problems arising in a radar system. A thorough familiarity with the waveforms normally encountered in radar circuits, a working knowledge of the frequencies and voltages to be expected, and a systematic approach to the problem are as much a part of the radar technician's equipment as are his voltmeter and his oscilloscope.

EXPERIMENT No. 39

SUBJECT

Trouble shooting the "A" scope sweep chain.

OBJECTIVE

To gain experience in trouble shooting this chain; to develop a trouble-shooting chart which, when combined with similar charts prepared for other chains, will act as a guide in trouble shooting the Advanced Radar System to be studied later in the course.

MATERIAL REQUIRED

Same as in EXPERIMENT No. 38.

INSTRUCTIONS

This sweep chain is the second of a group of four chains that will be combined in a later EXPERIMENT to form the Advanced Radar System. A trouble-shooting chart is to be prepared by each student, covering a step-by-step method for locating and eliminating faults in the chain with a minimum of time and effort. In form, this chart should be similar to the one prepared for the timer in EXPERIMENT No. 37. Consult various training manuals on military equipment, as a source of ideas.

PROCEDURE

1. Set up the blocking-oscillator timer and the "A" scope sweep chain as you did in EXPERIMENT No. 38. When it is operating correctly, call an instructor.

2. The instructor will insert troubles into your equipment.

Instructor's initials_______

3. Locate and remove these troubles, using a procedure that you consider suitable for use in your trouble-shooting chart.

4. Make a complete set of notes, to assist you in writing the trouble-shooting chart.

5. Fill out a JOB SHEET, and have the instructor check your work.

Instructor's initials_______

6. If time permits, you may ask that further troubles be placed in your equipment, and may remove them for extra credit, filling out a second JOB SHEET.

Instructor's initials_______

CONCLUSIONS

From your notes, prepare a complete trouble-shooting chart for the "A" scope sweep chain. Proceed as in EXPERIMENT No. 37, and according to the INSTRUCTIONS in this EXPERIMENT.

JOB SHEET

STUDENT'S NAME____

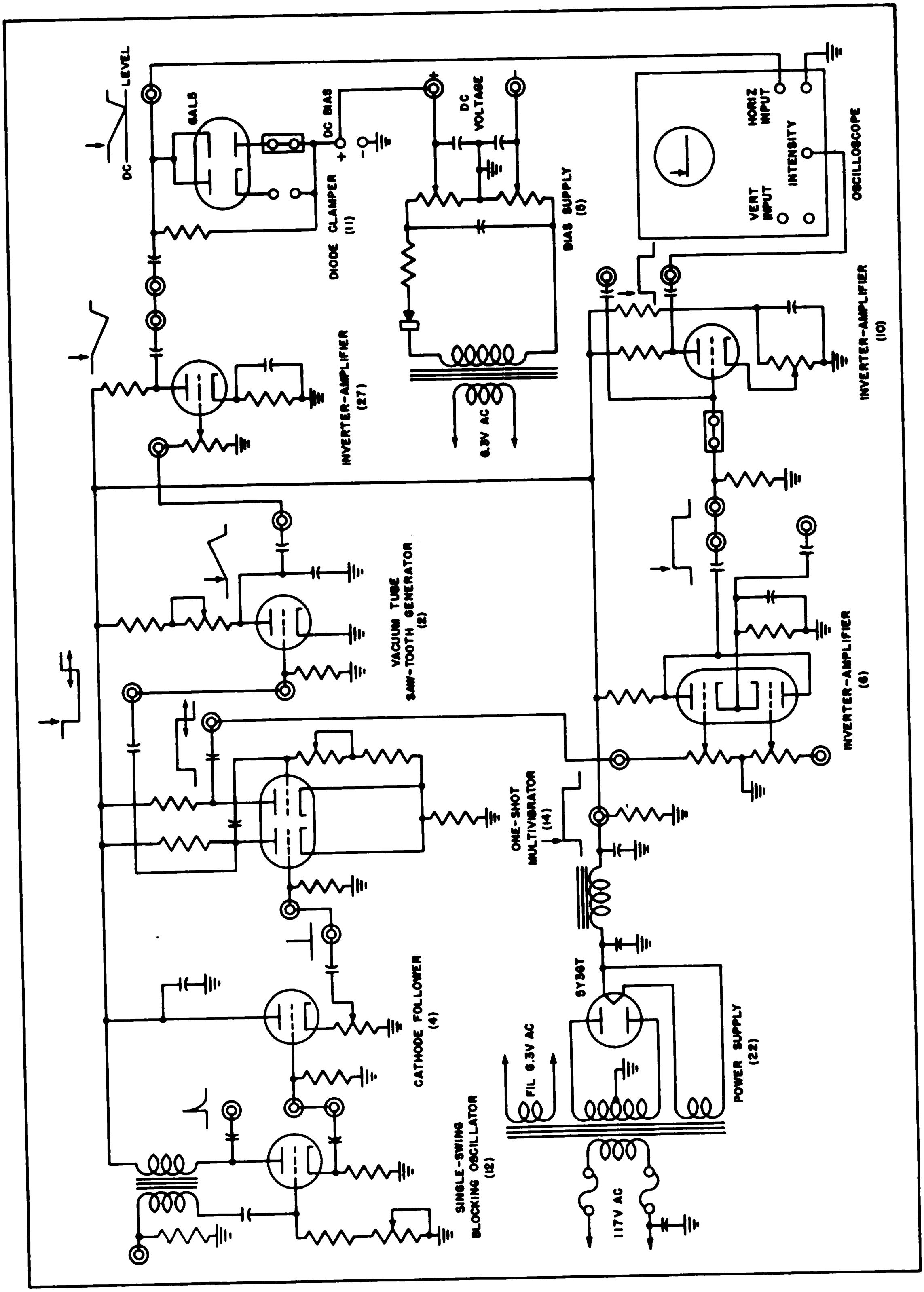
SECTION____

INDICATION (no output, distortion, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE EQUIPMENT.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)



Trouble-Shooting Diagram for "A" Scope Sweep Chain
(Waveforms are taken from output of each stage.)

STUDENT TROUBLE-SHOOTING CHART
(To be designed by student.)

LABORATORY PLAN No. 40

SUBJECT

The range-marker chain.

OBJECTIVE

To familiarize the student with the operation of the range-marker chain, and the output frequencies and waveforms developed in this chain.

MATERIAL REQUIRED

1. R-C Oscillator Chassis (3).
2. Series Diode Limiter Chassis (8).
3. Triode Limiter Chassis (10).
4. Shock-Excited Peaking Oscillator Chassis (15).
5. Cathode Follower Chassis (4).
6. Bias Supply Chassis (5).
7. Mixer Chassis (6).
8. Five-inch oscilloscope with leads.
9. Vacuum-tube voltmeter with leads.
10. A-F oscillator with leads.
11. Laboratory Chassis Mounting Rack.
12. Power Supply Chassis (22).

INTRODUCTION

The range-marker chain used in this EXPERIMENT will be used to furnish range markers for the indicator scope and to synchronize the single-swing blocking oscillator. This marker chain could, with additions, also be used to furnish the sweep and unblanking pulses.

One of the main advantages of range markers is that the estimation of range is made somewhat more accurate by their use, since they divide the trace into equal time intervals. Markers which appear on the sweep itself, rather than as marks on an overlaid scale, are preferable because they compensate for the effect of nonlinearity in the sweep.

SUBJECT MATERIAL

1. Have the students connect the equipment as shown in the block diagram in the EXPERIMENT.
2. A careful observation of the waveforms obtained should be made by the students. Check and make sure that the synchrograms are constructed properly.
3. Check all waveforms carefully, and initial each student's work before allowing him to proceed.
4. Keep a constant bench-to-bench check on the students' work as they proceed with the EXPERIMENT.

CONCLUSIONS

In this EXPERIMENT the range-marker chain was studied. It will be used in the Advanced Radar System to facilitate the measurement of range of a target. The marker chain used in this EXPERIMENT develops a group of fixed markers which are used to calibrate the range sweep. Therefore, the markers must be separated by known time intervals, and these time intervals must be uniform.

EXPERIMENT No. 40

SUBJECT

The range-marker chain.

OBJECTIVE

To study the circuit operation and the output frequencies, waveforms, and amplitudes developed in the range-marker chain to be used in the Advanced Radar System.

MATERIAL REQUIRED

1. R-C Oscillator Chassis (3).
2. Series Diode Limiter Chassis (8).
3. Triode Limiter Chassis (10).
4. Shock-Excited Peaking Oscillator Chassis (15).
5. Cathode Follower Chassis (4).
6. Bias Supply Chassis (5).
7. Mixer Chassis (6).
8. Five-inch oscilloscope with leads.
9. Vacuum-tube voltmeter with leads.
10. A-F oscillator with leads.
11. Laboratory Chassis Mounting Rack.
12. Power Supply Chassis (22).

INSTRUCTIONS

The range-marker chain to be studied during this EXPERIMENT is the third of a group of four chains that will comprise the Advanced Radar System. It will be used in that system not only to furnish range markers for the indicator scope, but also to trigger the triggered blocking oscillator. In addition to its value in showing the operation of a typical range-marker chain, this circuit is an excellent example of a method used to convert the output of a sine-wave generator into non-sinusoidal waveforms of the types required of a timer chain. This chain could, in fact, be used as a timer chain by the addition of a one-shot multivibrator, to furnish the sweep and unblanking gates.

The R-C oscillator (3) produces a sinusoidal output at a frequency of 200 c.p.s.

The series-diode limiter (8) is connected as a negative-limiting device; it removes the negative alternations of the sine waves produced by the oscillator. In order to minimize time delay (due to phase shift in the coupling circuit), the following changes must be made in the limiter circuit:

In the triode limiter circuit, remove the grid-limiting resistor, R2, and replace it with a shorting strip. If this resistor were not removed, the triode grid would not follow the positive-going input voltage supplied to it by the diode limiter, and the output of the triode would be reduced nearly to zero.

The output of the squaring circuit provides negative pulses of considerable amplitude, which are impressed upon the grid of the shock-excited peaking oscillator (15). These pulses, acting as a gate, drive the peaker into oscillation at a pulse repetition frequency equal to the frequency of the R-C oscillator. Therefore, 200 times per second, the peaker tube is cut off, and its highly damped tank circuit produces a sharp positive pulse, followed by a broad negative pulse of much lower amplitude.

The negative peaks are removed by impressing the waveform upon the grid of a cathode follower (4), which is biased beyond cutoff by the bias supply (5). The bias voltage can be adjusted to produce a perfectly straight base line supporting narrow positive marker pips having a pulse repetition frequency of 200 p.p.s.

The output of the cathode follower is fed into a mixer stage which is connected as a cathode follower. In a later EXPERIMENT, the other channel of this mixer will be used to combine the range-marker pips with a range notch, and to deliver the combined waveform to the vertical-deflection plates of the "A" scope indicator.

PROCEDURE

Connection and Testing

1. Insert SS-1 and SS-2 and remove SS-1 ALT and SS-2 ALT in the series diode limiter. Also remove C1 and replace it with a shorting strip.

2. Replace R2 with a shorting strip in the triode limiter, and change R3 to a 1 meg resistor.

3. Convert the cathode follower (4) for use with negative bias on the grid. To do this, plug in only the grid side of R1 and apply the bias to the other free end with an alligator clip fastened to a lead, that will plug into the bias jack. Connect the mixer for use as a cathode follower by removing C1 and inserting SS-2 ALT and SS-1 ALT.

4. Connect the equipment as shown in the block diagram of figure 1.

5. Connect the vertical scope lead to the OUTPUT jack of the R-C oscillator (3), and observe that the output is a series of sine waves. Adjust the frequency of the oscillator to about 200 cycles.

6. Connect the scope lead to the OUTPUT jack of the series diode limiter (8). Observe that the negative alternations of the sine waves have now been eliminated, leaving only the positive alternations.

7. Transfer the scope lead to the OUTPUT jack of the overdriven amplifier (10). A series of approximately rectangular square waves of considerable amplitude should be observed. Rotate the bias-control potentiometer, R5, of the overdriven amplifier over its entire range, and note that the greater the bias is made, the more the amplitude decreases. Set the bias-control knob at a position that will produce the greatest possible amplitude, consistent with the best square-wave output.

8. Connect the scope lead to the OUTPUT jack of the shock-excited peaking oscillator (15). With the damping potentiometer, R2, turned to its minimum-resistance position, a short train of damped waves, coincident with the negative pulse of each square wave, should be observed. Turn the damping resistor counterclockwise until the wave train damps out to a single positive pulse of minimum width, followed by a negative pulse. Leave the damping potentiometer in this position.

9. Transfer the scope lead to the OUTPUT jack of the cathode follower (4). With the negative-bias control knob of the bias supply (5) set to provide zero bias, the waveform from the cathode follower should be approximately the same as that obtained from the output of the peaker, except that it will have a lower amplitude. Turn the negative bias control slowly clockwise; observe that the output waveform of the cathode follower decreases, and that the negative pulses shrink until the base line of the trace is perfectly straight. Adjust the bias to a point where the negative pulse just disappears. A further increase in bias will decrease the amplitude of the positive pulses without improving their waveform.

10. Connect the scope lead to the OUTPUT jack of the mixer (6). Vary the gain control of Channel No. 1 of the mixer, and note that the same waveform occurs at the mixer output as was observed at the output of the cathode follower—a series of sharp, positive-going marker pips. Vary the mixer gain control over its entire range, and note any points at which distortion of the waveform occurs. Set the gain control at a point just above that at which distortion begins. (To do this you should adjust scope for 1 pulse and increase horizontal sweep length.

The waveform being delivered by the mixer is the series of range marks that this chain is intended to produce. They are spaced 5000 microseconds apart, and are quite narrow in comparison with the distance between them.

11. Demonstrate the operation of the range-marker chain to your instructor. Be prepared to answer any questions he may ask regarding its operation and adjustment.

Instructor's initials______

Construction of a Synchrogram

1. Refer to figure 2. In the space provided, record the indicated waveforms, being careful to place them in proper phase relationship with each other.

2. Make careful measurements of the voltage amplitude, and of the pulse widths in microseconds of each waveform, and enter these figures on your drawing.

CONCLUSIONS

1. What would happen if the coupling capacitor between the R-C oscillator and the series-diode limiter were to become short-circuited?

If the capacitor were to become shorted, a high positive d-c voltage (B+) would appear on the plate of the limiter. This voltage would keep the diode limiter conducting continuously, and there would be no a-c output.

2. Explain the operation of the series diode limiter and the overdriven amplifier in squaring the sine waves.

The series diode limiter clips off the negative alternation of the incoming sine wave. The remaining positive half-cycle drives the amplifier highly positive, causing the triode to act as a saturation limiter. Both half-cycles are, therefore, limited (the negative lobe by the diode, the positive lobe by the triode), and a square wave is produced as the output of the amplifier.

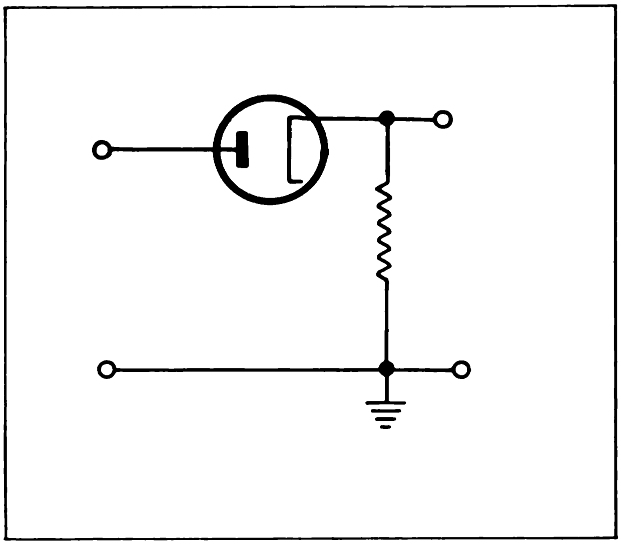
3. What changes would you make in the shock-excited peaking oscillator circuit in order to produce narrower range markers? Why?

Lower the LC product. Since $f = \frac{1}{2\pi\sqrt{LC}}$, decreasing the LC product increases the operating frequency, which means that each half-cycle (range marker) is of shorter duration (narrower).

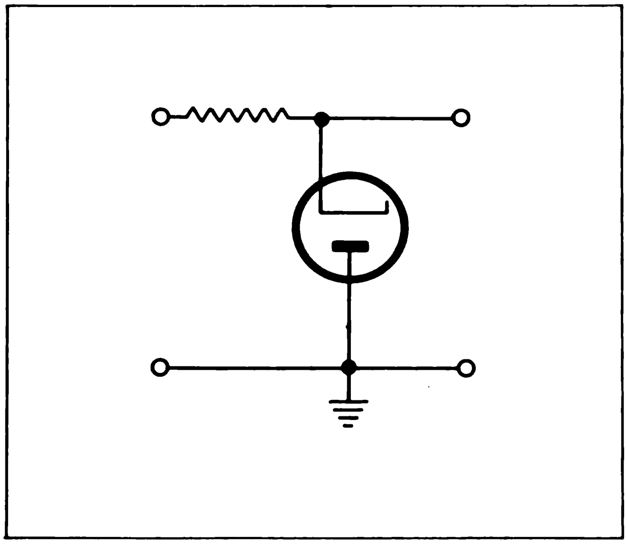
4. What other methods, besides the one used in this chain, might be employed to eliminate the negative pulses present in the output of the peaker? Draw a schematic diagram of each circuit you suggest.

5. Name two results of converting the mixer from its present connection as a cathode follower, and changing it into a plate-loaded amplifier.

a. Phase inversion is obtained.
b. Amplification results.



A Series Diode Limiter for Question 4 of Conclusions



A Parallel Diode Limiter of Question 4 of Conclusions

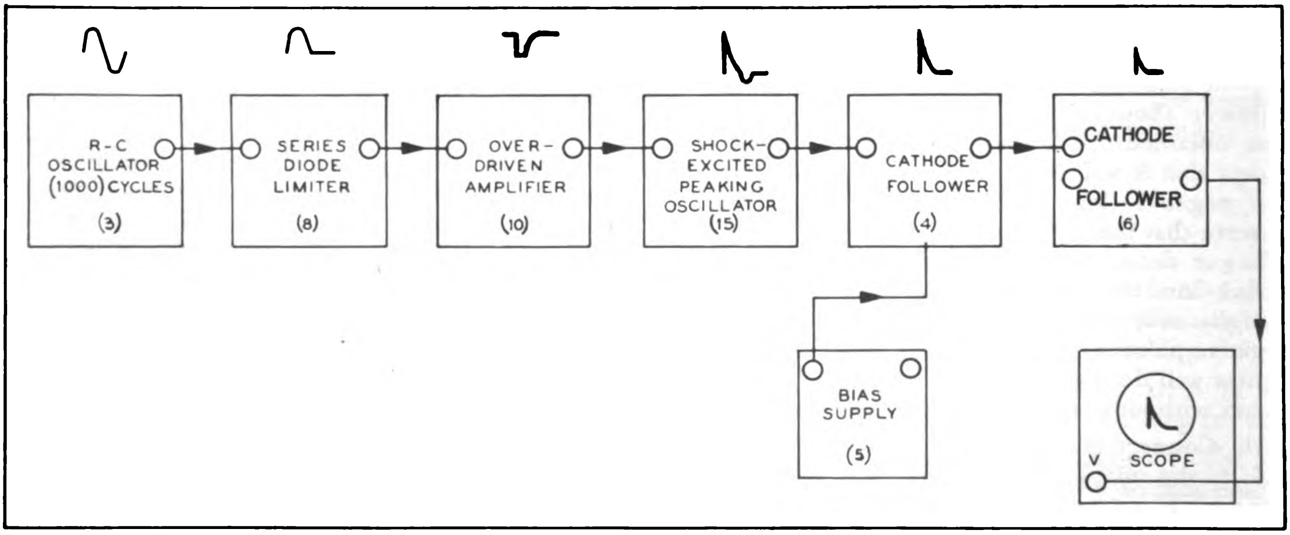


Figure 1. Block Diagram of Range-Marker Chain

A OUTPUT OF R-C OSCILLATOR	
B OUTPUT OF SERIES DIODE LIMITER	
C OUTPUT OF OVERDRIVEN AMPLIFIER	
D OUTPUT OF SHOCK-EXCITED PEAKING OSCILLATOR	
E OUTPUT OF CUTOFF-BIASED CATHODE FOLLOWER	
F OUTPUT OF MIXER	

Figure 2. Synchrogram of Waveforms Developed in Range-Marker Chain

LABORATORY PLAN No. 41

SUBJECT

Trouble shooting the range-marker chain.

OBJECTIVE

To assist the students in formulating a systematic method of trouble shooting a range-marker chain; and to have them develop a trouble-shooting chart and schematic diagram from the procedure they followed in the EXPERIMENT.

MATERIAL REQUIRED

Same as in EXPERIMENT No. 40.

INTRODUCTION

Quick and efficient location of troubles in a range-marker chain requires the use of a systematic trouble-shooting procedure. The range-marker chain is made up of various chassis (R-C Oscillator Chassis, Series Diode Limiter Chassis, Triode Limiter Chassis, etc.) that were used in the previous EXPERIMENT.

SUBJECT MATERIAL

1. Before coming to class, the students should have prepared trouble-shooting charts for the range-marker chain, in accordance with the JOB SHEET for listing troubles, which is attached to the EXPERIMENT.

2. The students should use these trouble-shooting charts when correcting troubles. The troubles are to be placed in the circuit by the instructor.

3. Maintain a bench-to-bench check on the students' work during the laboratory session, and correct their procedures, as necessary.

4. Correct the charts and JOB SHEETS prepared by the students, and grade their work for correctness and completeness.

CONCLUSIONS

Trouble shooting of this chain is done rapidly and easily if the accepted method of localizing, isolating, and locating is used.

EXPERIMENT No. 41

SUBJECT

Trouble shooting the range-marker chain.

OBJECTIVE

To gain experience in locating troubles in the range-marker chain; to develop a trouble-shooting chart suitable for use when investigating the Advanced Radar System.

MATERIAL REQUIRED

Same as in EXPERIMENT No. 40.

INSTRUCTIONS

This range-marker chain is one of the components that is to be combined in the Advanced Radar System to be studied later. As in the case of the timer and the sweep chain, a trouble-shooting chart is to be developed by each student. The chart will cover a step-by-step procedure for locating troubles in the range-marker chain; it must be compiled in the same form as were the charts for the two previous chains.

PROCEDURE

1. Set up the range-marker chain as you did in EXPERIMENT No. 40. When it is operating properly, call the instructor.
2. The instructor will insert troubles into your equipment.

Instructor's initials______

3. Locate and remove these troubles, using a procedure that you consider suitable for use in your trouble-shooting chart.
4. Make a complete set of notes, to assist you in writing the trouble-shooting chart.
5. Fill out a JOB SHEET, and have the instructor check your work.

Instructor's initials______

6. If time permits, you may ask that further troubles be placed in your equipment, and may remove them for extra credit, filling out a second JOB SHEET.

Instructor's initials______

CONCLUSIONS

From your notes, prepare a complete trouble-shooting chart for the range-marker chain. Proceed as in EXPERIMENT Nos. 37 and 39, and according to the INSTRUCTIONS in this EXPERIMENT.

JOB SHEET

STUDENT'S NAME____

SECTION____

INDICATION (no output, distortion, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE EQUIPMENT.

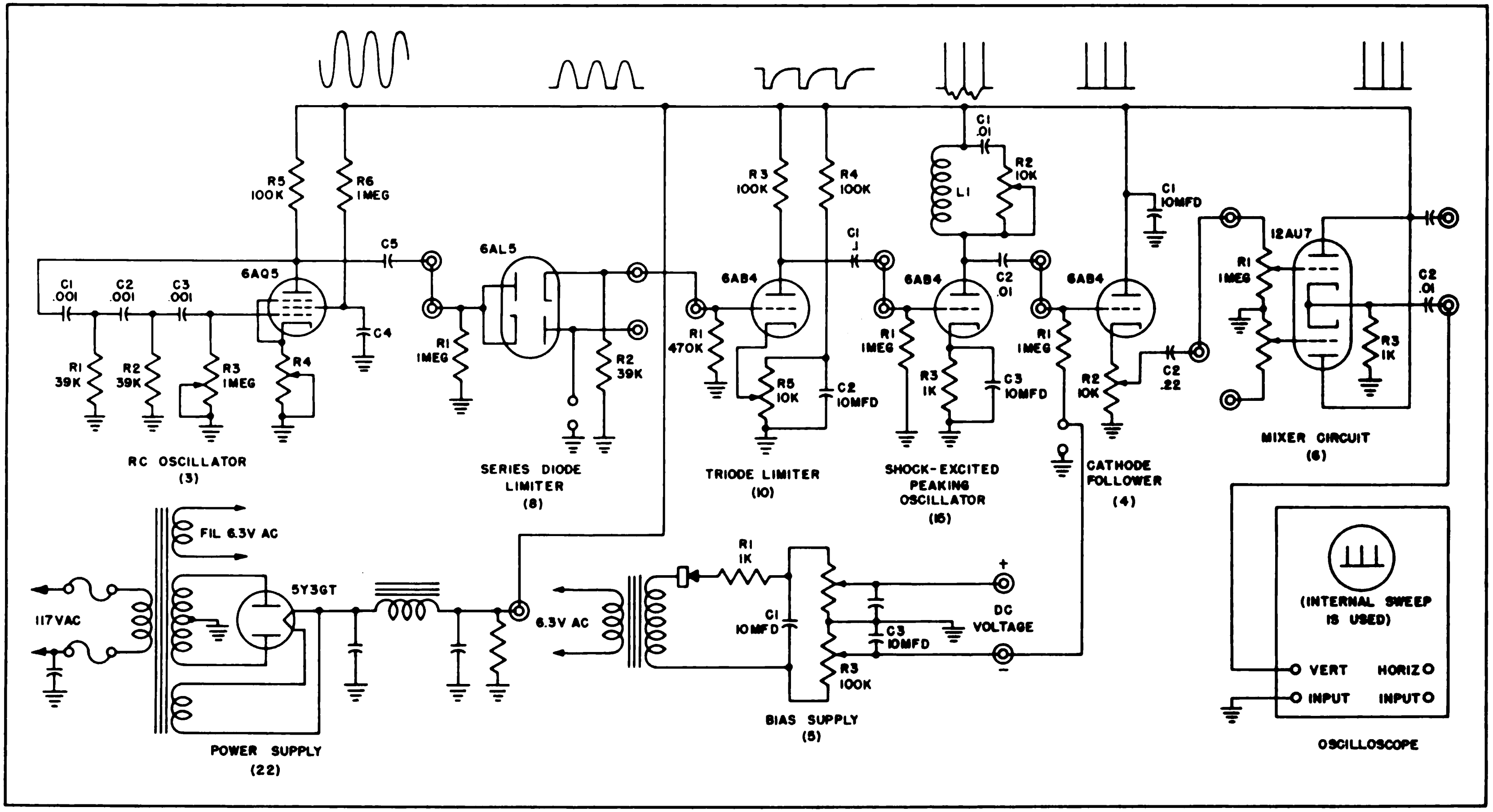
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.

(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.

(Describe method used.)



Trouble-Shooting Diagram for Range-Marker Chain
(Waveforms are taken from output of each stage.)

STUDENT TROUBLE-SHOOTING CHART
(To be designed by student.)

LABORATORY PLAN No. 42

SUBJECT

The range-notch chain.

OBJECTIVE

To familiarize the students with the circuit operation of the range-notch chain; and to have the students develop a trouble-shooting chart and schematic diagram for this chain.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Cathode Follower Chassis (4).
3. One-Shot Multivibrator Chassis (13).
4. Differentiator-Integrator Chassis (7).
5. Parallel Diode Limiter Chassis (9).
6. Bias Supply Chassis (5).
7. Mixer Chassis (6).
8. Five-inch oscilloscope with leads.
9. Vacuum-tube voltmeter with leads.
10. A-F oscillator with leads.
11. Laboratory Chassis Mounting Rack.
12. Power Supply Chassis (22).

INTRODUCTION

The difficult problem of firing a gun accurately can be simplified considerably if the exact distance between the gun and the target can be determined. Radar provides a means of finding this distance by measuring the time required for r-f energy to travel out to a target, be reflected, and to return. Precise measurement of range requires the accurate measurement of extremely short time intervals. These are measured by some means of introducing an accurately calibrated variable delay between the transmitted pulse and the echo pulses, as seen on the indicator screen. A one-shot multivibrator is used in this EXPERIMENT to provide a range-notch pulse (variable delay) for measuring the range of the target from the radar antenna.

SUBJECT MATERIAL

1. Have the students connect the equipment and make all adjustments, as directed in the EXPERIMENT.

2. The students should make drawings of the waveforms obtained. Supervise the students in the construction of a synchrogram.

3. Inspect and initial the students' work, as called for in the EXPERIMENT. Keep a constant bench-to-bench check on the students' technique and procedure.

4. Insert troubles into the equipment, and have the students follow the trouble-shooting procedure used in previous EXPERIMENTS.

CONCLUSIONS

The circuits that control the range-notch chain are connected to an electronic computer which indicates, directly on the dial, the distance between the target and the radar antenna. No estimation is required, and the accuracy may be extremely high. In airborne radar, the information transmitted to the electronic computer is used in connection with pattern bombing or navigation.

EXPERIMENT No. 42

SUBJECT

The range-notch chain.

OBJECTIVE

To become familiar with the circuit operation of a range-notch chain similar to those used in precision computers; to develop a trouble-shooting chart for this chain.

MATERIAL REQUIRED

1. Single-Swing Blocking Oscillator Chassis (12).
2. Cathode Follower Chassis (4).
3. One-Shot Multivibrator Chassis (13).
4. Differentiator-Integrator Chassis (7).
5. Parallel Diode Limiter Chassis (9).
6. Bias Supply Chassis (5).
7. Mixer Chassis (6).
8. Five-inch oscilloscope with leads.
9. Vacuum-tube voltmeter with leads.
10. A-F oscillator with leads.
11. Laboratory Chassis Mounting Rack.
12. Power Supply Chassis (22).

INSTRUCTIONS

As was indicated in EXPERIMENT No. 34, on the Basic Radar System, range marks are useful for making quick estimates of the distance from the radar equipment to a moving target. The accuracy of the results, however, depends to a large extent upon the accuracy with which the operator can judge the distance represented by the spacing between the target appearing on his scope and the range marks adjacent to it. This degree of accuracy is entirely adequate for search-radar use, but is sometimes insufficient for the more exacting requirements of gun-laying equipment.

More accurate equipments employ a range notch—a pip that can be moved back and forth along the sweep until it rests directly under the target. The circuits that control the position of this range notch are connected to an electronic computer which indicates directly on a dial the distance from the radar equipment to the target. No estimation is required, and the accuracy can be made extremely high.

Various airborne radars also use the range notch in connection with automatic-tracking circuits. The operator adjusts the range-notch control until the notch rests directly on the target. He then manipulates the knob for a short time, keeping the notch and the target at the same point on the sweep. After a few seconds of manual tracking, the automatic circuits of the radar installation take over, and keep the notch and the target together without further attention from the operator. The information transmitted to the system by the range-notch circuits is used in connection with pattern bombing or navigation.

This chain has, of course, been reduced to its simplest form. It presents the basic idea without the complications and refinements (such as expanded sweep and receiver gating) normally required for its satisfactory operation.

The operation of the chain is as follows:

A positive-going trigger pulse from the timer is applied to the input of the one-shot multivibrator (13). The multivibrator produces rectangular waves, the position of whose trailing edges can be adjusted by varying the grid-leak potentiometer, R6. Since the rectangular wave starts at the same instant that the trigger pulse impinges upon the multivibrator grid, the trailing edge can be made to occur any reasonable number of microseconds *after* the trigger pulse. The multivibrator, therefore, acts as a delay circuit whose delay is adjustable by means of R6.

The output of the multivibrator is fed into a differentiator (7), which converts the leading edges of the rectangular waves into positive pips, and produces negative pips coincident with the adjustable trailing edges. The width of these pips can be adjusted by varying the potentiometer of the differentiator circuit.

The positive pips are then removed by a parallel diode limiter (9), whose clipping level is adjustable by means of a variable negative bias on the cathode of the diode tube.

The output of the parallel diode limiter is a series of negative pips of adjustable sharpness, whose position, in relationship to the trigger pulses, can be adjusted over a wide range. These pips are fed through Channel No. 2 of a cathode-follower mixer (6), and delivered to the vertical-deflection plates of the scope.

PROCEDURE

Connection and Adjustment

1. In the single-swing blocking oscillator, insert a 100K resistor for SS-1, and insert SS-2. Insert SS-1 in normal position in the one shot multivibrator. Insert SS-1 in ALT 1 position in the parallel diode limiter and arrange the bias supply for negative bias. Insert SS1 and SS2 in ALT positions in the mixer, and remove C1.

2. Set up the equipment as shown in the block diagram of figure 1.

3. Connect the scope lead to the OUTPUT jack of the single-swing blocking oscillator (12), adjust the frequency of the oscillator to about 30 p.p.s., and inspect the waveform for proper shape and amplitude.

4. Transfer the scope lead to the OUTPUT jack of the cathode follower (4), and check the waveform and amplitude. Be sure that the amplitude falls within the range that will produce correct triggering of the one-shot multivibrator.

5. Connect the scope to the top OUTPUT jack of the one-shot multivibrator (13). Check for proper waveform, and make sure that the gate width can be varied over a wide range by turning the knob of grid-leak potentiometer R6.

6. Adjust the negative bias control knob of the bias supply (5) until the last trace of the positive pips just disappears from the waveform appearing at the limiter OUTPUT jack. Leave the knob at this position.

7. Transfer the scope lead to the OUTPUT jack of the mixer (6). Vary the Channel No. 1 gain-control knob of the mixer over its entire range, and look for traces of cutoff limiting. Set the gain-control knob at the position that gives maximum voltage without distortion.

8. Demonstrate the operation of the range-notch chain to the instructor. Be prepared to answer any questions he may ask regarding its operation and adjustment.

Instructor's initials________

Construction of a Synchrogram

1. Refer to figure 2. In the space provided, record the indicated waveforms, being careful to place them in proper phase relationship with each other.

2. Make careful measurements of the voltage amplitude and of the pulse width in microseconds of each waveform, and enter these figures in your drawing.

Trouble Shooting

1. The instructor will insert troubles into your equipment.

Instructor's initials________

2. Locate and remove these troubles, using a procedure that you consider suitable for use in your trouble-shooting chart.

3. Make a complete set of notes, to assist you in writing the trouble-shooting chart.

4. Fill out a JOB SHEET, and have the instructor check your work.

5. If time permits, you may ask that further troubles be placed in your equipment, and may remove them for extra credit, filling out a second JOB SHEET.

Instructor's initials________

CONCLUSIONS

From your notes, prepare a complete trouble-shooting chart for the range-notch chain. Proceed as in previous EXPERIMENTS.

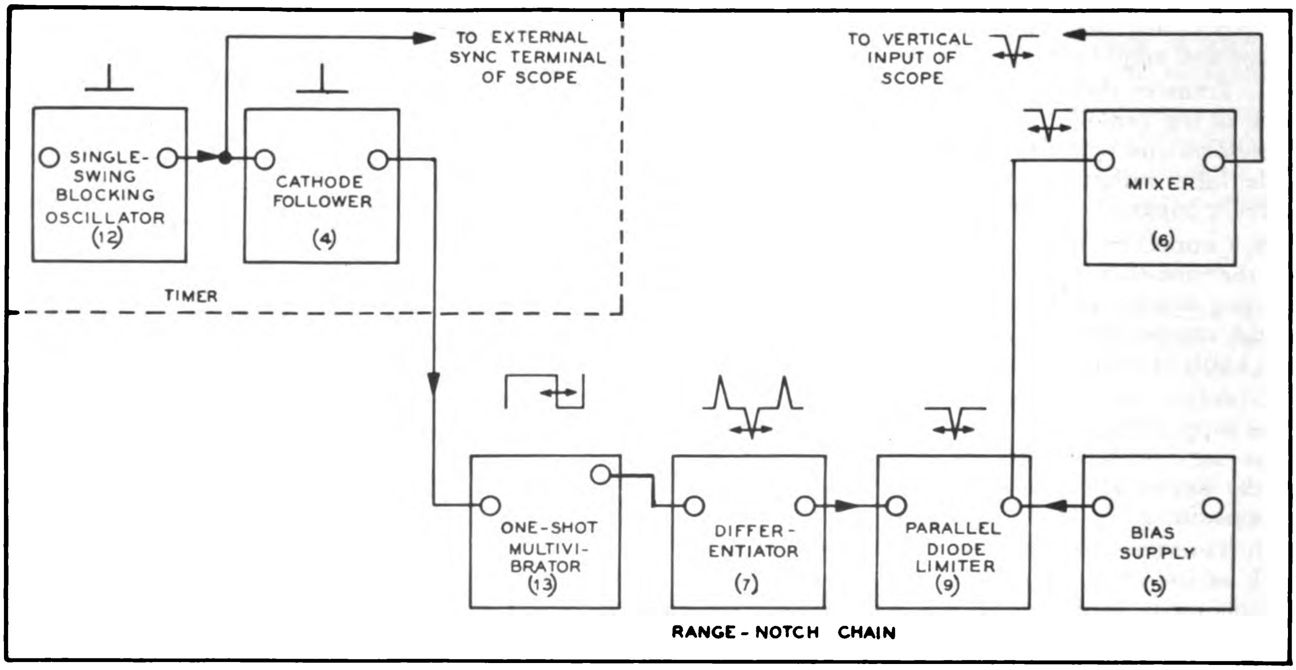
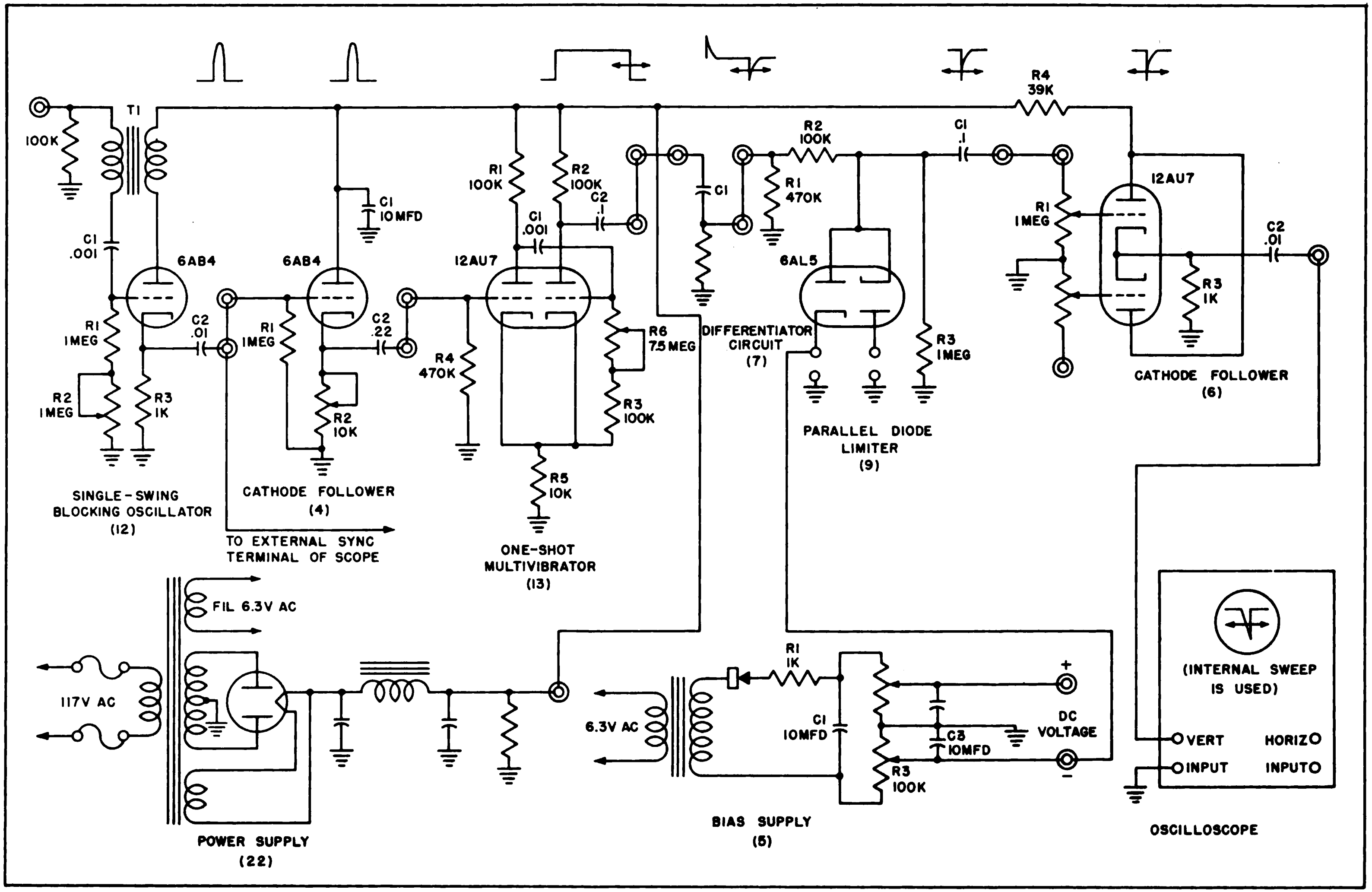

TO EXTERNAL SYNC TERMINAL OF SCOPE
TO VERTICAL INPUT OF SCOPE
SINGLE-SWING BLOCKING OSCILLATOR (12)
CATHODE FOLLOWER (4)
TIMER
MIXER (6)
ONE-SHOT MULTIVIBRATOR (13)
DIFFERENTIATOR (7)
PARALLEL DIODE LIMITER (9)
BIAS SUPPLY (5)
RANGE-NOTCH CHAIN

Figure 1. Block Diagram of Equipment Used in Studying the Range-Notch Chain

A TRIGGER PULSES FROM TIMER	
B OUTPUT OF MULTIVIBRATOR	
C OUTPUT OF DIFFERENTIATOR	
D OUTPUT OF PARALLEL DIODE LIMITER	
E OUTPUT OF MIXER (RANGE NOTCH)	

Figure 2. Synchrogram of Waveforms Developed in Range-Notch Chain



Trouble-Shooting Diagram for Range-Notch Chain
(Waveforms are taken from output of each stage.)

STUDENT TROUBLE-SHOOTING CHART

(To be designed by student.)

LABORATORY PLAN No. 43

SUBJECT

An Advanced Radar System.

OBJECTIVE

To familiarize the students with the characteristics, operation, and waveforms of the Advanced Radar System using "A" scope presentation.

MATERIAL REQUIRED

1. R-C Oscillator Chassis (3).
2. Series Diode Limiter Chassis (8).
3. Triode Limiter Chassis (10).
4. Shock-Excited Peaking Oscillator Chassis (15).
5. Cathode Follower Chassis (4).
6. Audio Voltage Amplifier (27).
7. Mixer (6).
8. Step Counting Circuit (17).
9. Triggered Block Oscillator (18).
10. Diode Clamper (11).
11. Power Supply (22) (2 required).
12. Thyratron Saw-tooth Generator (19).
13. On-Shot Multivibrator (13).
14. Differentiator-Integrator (7).
15. Parallel Diode Limiter (9).
16. Phase Splitter (28).
17. Bias Supply (5).
18. Five-inch oscilloscope with leads.
19. Vacuum-tube voltmeter with leads.
20. A-F oscillator with leads.
21. Laboratory Chassis Mounting Rack.

INTRODUCTION

Radar systems now in existence vary greatly in detail. They may be simple, or, if more accurate data is required, they may be highly refined. The principles of operation, however, are essentially the same for all systems. Thus a single radar system can be realized in which the functional requirements hold equally well for all specific equipment. The varying details are due to a choice of specific circuits to fulfill these general functional requirements.

The chassis used in making up the Advanced Radar System have been used in the preceding EXPERIMENTS. The waveforms obtained in this EXPERIMENT will be used to produce a type "A" scope presentation on the indicator screen.

SUBJECT MATERIAL

1. Have the students set up the equipment and make all of the necessary adjustments.
2. Have the students make a careful observation of the waveforms that are taken, and supervise the students in the construction of a synchrogram.
3. Check all waveforms carefully, and initial each student's work before allowing him to proceed.
4. Keep a constant bench-to-bench check on the students' technique and procedure.

CONCLUSIONS

The Advanced Radar System used in this EXPERIMENT is typical of many radar systems in actual use. Although parts in large radar systems are physically different from corresponding parts in smaller radar systems such as this, the theory and practice, which is taught the students in this EXPERIMENT, applies in either case.

EXPERIMENT No. 43

SUBJECT

An Advanced Radar System.

OBJECTIVE

To become familiar with the circuit operation of a radar system containing a timer, an "A" scope sweep chain, a range-marker chain, and a range-notch chain; to study all the waveforms involved in such a system, and to analyze their time relationships; to observe the "A" scope presentation that results from a combination of these four chains.

MATERIAL REQUIRED

1. R-C Oscillator Chassis (3).
2. Series Diode Limiter Chassis (8).
3. Triode Limiter Chassis (10).
4. Shock-Excited Peaking Oscillator Chassis (15).
5. Cathode Follower Chassis (4).
6. Audio Voltage Amplifier (27).
7. Mixer (6).
8. Step-Counting Circuit (17).
9. Triggered Block Oscillator (18).
10. Diode Clamper (11).
11. Power Supply (22) (2 required).
12. Thyratron Saw-tooth Generator (19).
13. One-Shot Multivibrator (13).
14. Differentiator-Integrator (7).
15. Parallel Diode Limiter (9).
16. Phase Splitter (28).
17. Bias Supply (5).
18. Five-inch oscilloscope with leads.
19. Vacuum-tube voltmeter with leads.
20. A-F oscillator with leads.
21. Laboratory Chassis Mounting Rack.

INSTRUCTIONS

The system to be assembled and studied during this EXPERIMENT contains all the basic elements found in radar equipments, with the exception of a transmitter, receiver, and antenna system. These elements have all been studied in the radio laboratory, and will not be considered here because of the complications they would add to the laboratory work.

The system you are about to construct places upon the scope screen a stationary trace of adjustable duration. The trace is controlled by a master-oscillator stage. It presents range markers of known time separation, as an aid in estimating distance from the radar receiver to a distant target. It is equipped with a movable marker of the type used in gun-laying, bomb-release work, and tracking. Thorough familiarity with the operation and trouble shooting of this system will equip the student to undertake the specialized study of individual military radar equipments.

The four chains that comprise this system have already been studied individually. The student is urged to review the EXPERIMENTS dealing with these chains, and to study their block diagrams and the synchrograms prepared in connection with each. Some necessary changes have been made in this circuit.

Briefly, the system operates as follows:

The range-marker chain is driven by an R-C oscillator (3) operating at about 136 cycles per second. Its sine-wave output is converted into square waves by the limiter-amplifier (8 and 10), and is used to gate a shock-excited peaker (15), whose output is limited by a cathode follower (4) and appears in the form of narrow, positive-going range markers, spaced about 7000 microseconds apart.

These range markers are fed through one channel of a mixer (6) to the vertical-deflection plates of a scope. They are also fed to the step counting circuit and diode limiter to drive the saw-tooth generator and the one-shot multivibrator in the range-notch chain.

The one-shot multivibrator (13), produces the variable sweep gate. The same multivibrator also produces another gate which is applied to the external sync terminal of the scope.

The output of the range-notch delay multivibrator (13) is differentiated by Chassis No. 7, after which the positive pips are removed by the parallel diode limiter (9) and its associated bias supply (5), and the remaining negative pulse is applied through the mixer (6) to the vertical-deflection plates of the scope. There it appears among the range markers as a variable-position negative range notch.

PROCEDURE

Connection and Adjustment

1. Set up the equipment as shown in the diagram of figure 1. Check the part sizes and posi-

tions of shorting strips in each chassis with the overall schematic diagram in the next EXPERIMENT before inserting each chassis.

2. When you have completed all the connections shown in figure 1, set the RC oscillator amplitude control to maximum and set the frequency control to about 136 cps.

3. Set the triode limiter for long sharp negative pulses with no positive ripples.

4. Adjust the shock-excited peaking oscillator for a single sharp positive and a single sharp negative spike for each input pulse.

5. Adjust the cathode follower for a single sharp positive spike for each positive spike from the peaking oscillator.

6. Adjust the inverter amplifier for a single large negative spike for each input spike.

7. Adjust mixer No. 1 input control for ½ inch positive spike with a straight base line, with the scope connected to the mixer output jacks.

8. Adjust the triggered blocking oscillator for from 6 to 20 steps. Make a fine adjustment of the triggered blocking oscillator for a steady positive and negative pulse from the output of the diode limiter (chassis 11).

9. Adjust the thyratron sawtooth generator for a single steady sawtooth wave for each input pulse.

10. Check output No. 1 of the one-shot multivibrator. You should be able to vary the width of the negative square wave by adjusting R6. You may have to make a fine adjustment of the triggered blocking oscillator (R4) to sync the pattern on the scope.

11. Check the output of the parallel diode limiter for a large steady negative spike. To stabilize the spike, you may have to make another fine adjustment of the triggered blocking oscillator.

12. Check the output of the mixer. Adjust channel No. 2 input (R2) for a ¼ inch negative range notch on the scope.

13. Switch the scope to external sync and external sweep. Make final adjustments of the triggered blocking oscillator and the thyratron sawtooth generator for a stable pattern. You should have a number of steady positive range marks and a negative range notch that you can move along the base line from the extreme left toward the right from ½ to ⅔ the distance across the scope screen.

14. When you have completed setting up and adjusting the equipment, slowly vary the count down by varying R4 on the triggered blocking oscillator. This will change the number of range marks and range notches. However, the time represented between each range mark remains the same since it is determined by the frequency of the RC oscillator. At 136 cps, the time between range marks is 7,353 microseconds.

15. When you have completed all adjustments, have the instructor inspect your results.

Instructor's initials________

Construction of a Synchrogram

On pages 375 to 377, construct a synchrogram of all the waveforms developed in the system. Be particularly careful that all phase relationships are correct.

CONCLUSIONS

1. Discuss, in not fewer than 200 words, the uses to which equipment similar to this Advanced Radar System could be put in actual military operations.

2. What additional equipment would be necessary in order to convert the system used in this EXPERIMENT into a complete radar capable of making an "A" type presentation? Discuss fully, and show by block diagrams, how the additional equipment would be connected to the present system (page 373.)

a. The range-marker circuit supplies a trigger for the timer, and also provides markers, at a constant rate, to the indicator, permitting visual distance measurements.

b. The timer supplies the synchronizing signals which time the transmitted pulses, the sweep and unblanking circuits, and other associate circuits.

c. The transmitter generates the R-F energy in the form of short, powerful pulses.

d. The antenna system takes the R-F energy from the transmitter, radiates it in a highly directional beam, receives any returning echoes, and passes these echoes on to the receiver.

e. The receiver amplifies the weak R-F echoes and converts them into video information to be applied to the indicator.

f. The indicator produces a visual indication of the echo pulses in a manner which furnishes the required information.

g. The power supply furnishes all A-C and D-C voltages required by the system components.

Block Diagram of a Complete Radar System for Question 2

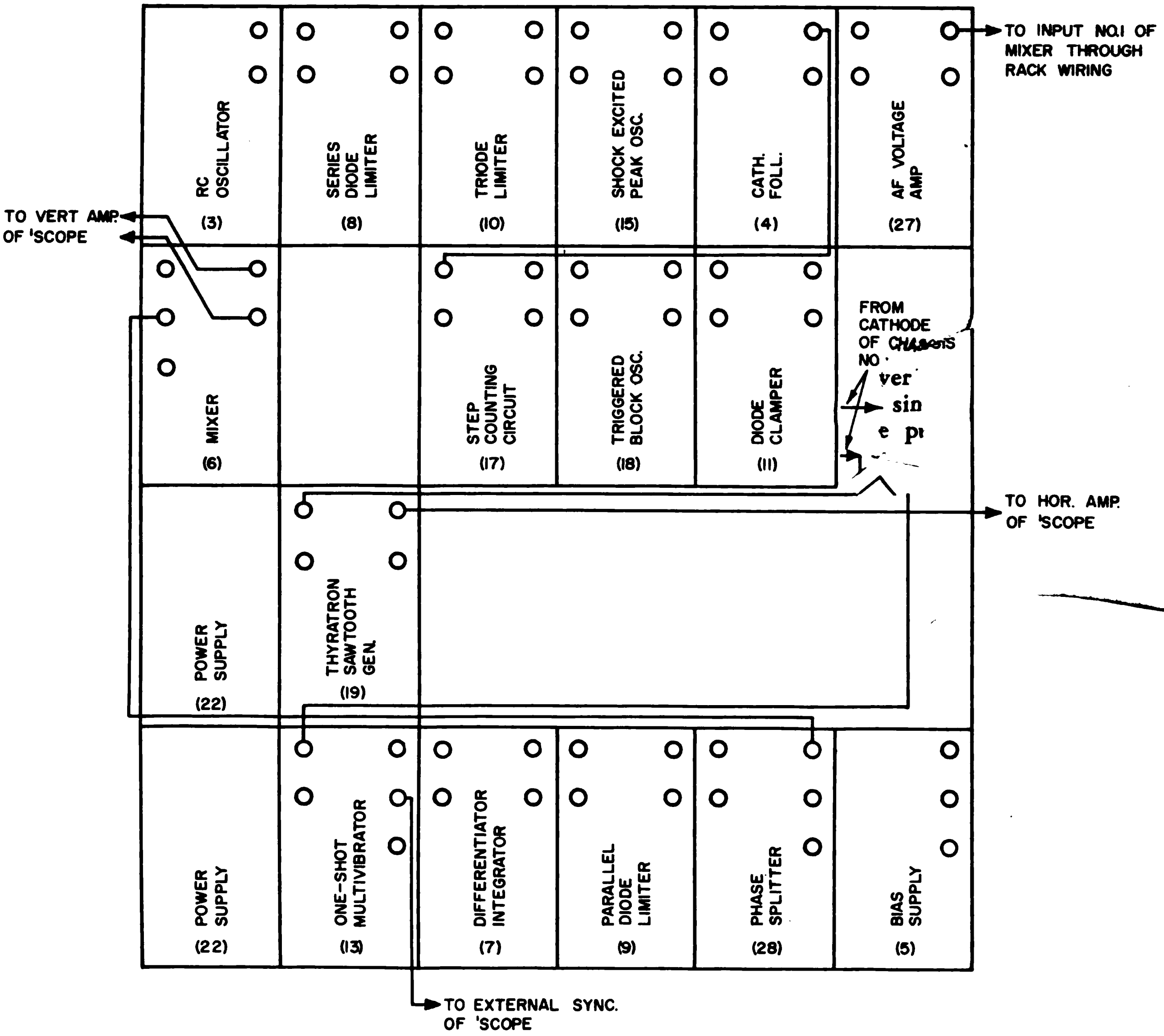

TO INPUT NO.1 OF MIXER THROUGH RACK WIRING
RC OSCILLATOR (3)
SERIES DIODE LIMITER (8)
TRIODE LIMITER (10)
SHOCK EXCITED PEAK OSC. (15)
CATH. FOLL. (4)
AF VOLTAGE AMP (27)
TO VERT AMP. OF 'SCOPE
MIXER (6)
STEP COUNTING CIRCUIT (17)
TRIGGERED BLOCK OSC. (18)
DIODE CLAMPER (11)
FROM CATHODE OF CHASSIS NO.
ver
sin
e p
TO HOR. AMP. OF 'SCOPE
POWER SUPPLY (22)
THYRATRON SAWTOOTH GEN. (19)
POWER SUPPLY (22)
ONE-SHOT MULTIVIBRATOR (13)
DIFFERENTIATOR INTEGRATOR (7)
PARALLEL DIODE LIMITER (9)
PHASE SPLITTER (28)
BIAS SUPPLY (5)
TO EXTERNAL SYNC. OF 'SCOPE

Figure 1. Equipment Diagram of Advanced Radar System

SYNCHROGRAM OF WAVEFORMS DEVELOPED IN THE ADVANCED RADAR SYSTEM

RANGE MARKER CHAIN

A R-C SINE WAVE OSCILLATOR 136 CPS	
B SERIES-DIODE LIMITER	
C TRIODE LIMITER	
D SHOCK-EXCITED PEAKING OSCILLATOR	
E CATHODE FOLLOWER (RANGE MARKERS)	
F MIXER (RANGE MARKERS AND RANGE NOTCH)	

SYNCHROGRAM OF WAVEFORMS DEVELOPED IN THE ADVANCED RADAR SYSTEM (Cont.)

SWEEP CHAIN

G INPUT TO STEP COUNTER	
H GRID OF TRIGGERED BLOCKING OSCILLATOR	
I OUTPUT OF TRIGGERED BLOCKING OSCILLATOR	
J DIODE LIMITER	
K THYRATRON SAW-TOOTH GENERATOR	

SYNCHROGRAM OF WAVEFORMS DEVELOPED IN THE ADVANCED RADAR SYSTEM (Cont.)

RANGE NOTCH CHAIN

L ONE-SHOT MULTIVIBRATOR	
M DIFFERENTIATOR	
N PARALLEL DIODE LIMITER	
O CATHODE FOLLOWER	

LABORATORY PLAN No. 44

SUBJECT

Trouble shooting the Advanced Radar System.

OBJECTIVE

To assist the student in formulating a systematic method of combining into one master trouble-shooting plan the individual trouble-shooting charts prepared for individual radar chains, and to familiarize him with the use of this plan in locating and removing troubles from the Advanced Radar System.

MATERIAL REQUIRED

Same as in EXPERIMENT No. 43.

INTRODUCTION

In previous EXPERIMENTS the students were taught a systematic procedure for the "Localize, Isolate, and Locate" method of trouble shooting individual chains in the radar system. The advanced radar system in this EXPERIMENT is made up of various chains (range-marker chain, sweep chain, range-notch chain, and power supply).

Since most of the circuits to be studied in this radar system have been analyzed individually, and then combined into the Advanced Radar System, the student has gained a theoretical knowledge of circuit operation and a practical experience in handling the equipment used.

SUBJECT MATERIAL

1. Before coming to class, the students should have prepared a trouble-shooting chart and schematic diagram on the Advanced Radar System, in accordance with the JOB SHEET for listing troubles, which is attached to the EXPERIMENT.

2. Check to see if the students have connected the equipment as shown in the block diagram in EXPERIMENT No. 43.

3. The students should use their trouble-shooting charts when correcting troubles in the Advanced Radar System. The troubles are to be placed in the radar system receiver by the instructor.

4. The students should enter on their JOB SHEETS each trouble corrected.

5. Check all waveforms carefully, and initial each student's work before allowing him to proceed.

6. Maintain a bench-to-bench check on the students' work during the laboratory session, and correct procedures, as necessary.

7. Correct the trouble-shooting chart and schematic diagram prepared by the students, and grade the work for correctness and completeness.

CONCLUSIONS

A comprehensive study of the material supplied in this EXPERIMENT should furnish the student with a practical basic background for servicing radar systems. The radar system studied herein can be considered as typical, with respect to trouble shooting, and an equivalent procedure will be found applicable in all phases of radar servicing.

EXPERIMENT No. 44

SUBJECT

Trouble shooting the Advanced Radar System.

OBJECTIVE

To combine into one master trouble-shooting plan the individual trouble-shooting charts prepared for individual radar chains; to use this plan in locating and removing troubles from the Advanced Radar System.

MATERIAL REQUIRED

Same as in EXPERIMENT No. 43.

INSTRUCTIONS

This EXPERIMENT marks the culmination of your experimental work in radar circuits and systems. Most of the important circuits used in modern radar equipments have been studied individually, then have been combined into laboratory-type systems that duplicate the operation of radar timers and indicators. In this process, you have gained a theoretical knowledge of circuit operation and practical experience in handling the apparent discrepancies that frequently arise between pure theory and actual practice.

As a practical test of your progress, this EXPERIMENT is devoted to the trouble shooting of the most elaborate radar system it was practical to devise, using the laboratory chassis available. The Advanced Radar System presents, in miniature, the basic problems that will be met in maintaining *any* radar equipment—from the simplest IFF or altimeter to the most elaborate heavy ground radar installation. The essential tools are the same in all cases: An oscilloscope, a voltmeter, and frequency-measuring equipment. The requirements placed upon the radar technician are also the same in all cases: Knowledge of the circuit operation; familiarity with the block diagram of the equipment; practical experience in recognizing the symptoms of troubles; and the ability to follow a logical step-by-step procedure for locating troubles and removing them.

The troubles inserted into your equipment during this EXPERIMENT will be more numerous and more difficult than any that were injected in previous EXPERIMENTS. The manner in which you conduct this EXPERIMENT will be used as a final test of what you have learned in the radar laboratory.

PROCEDURE

Completion of Master Trouble-Shooting Plan

1. Complete a trouble shooting chart covering the complete radar system.

2. Assign Major Test Points where they are needed, to assist you in localizing trouble to one particular unit of the equipment. Do not overlook the fact that the Laboratory Chassis Mounting Rack is an integral part of the system.

3. Give instructions for using these Major Test Points in localizing trouble.

4. Present this master plan to the instructor for a quick check before proceeding.

Instructor's initials______

Trouble Shooting

1. The instructor will insert trouble into your equipment.

Instructor's initials______

2. Locate and remove this trouble.

3. Fill out a JOB SHEET, describing fully the symptoms observed, the steps taken, and the troubles found.

4. Have the instructor check your work. He may elect to insert additional troubles. If he does, continue trouble shooting until the instructor is satisfied with your methods. Fill out an additional JOB SHEET for each group of troubles inserted.

Instructor's initials______

CONCLUSIONS

Submit your master trouble-shooting plan for detailed inspection and grading.

JOB SHEET

STUDENT'S NAME____

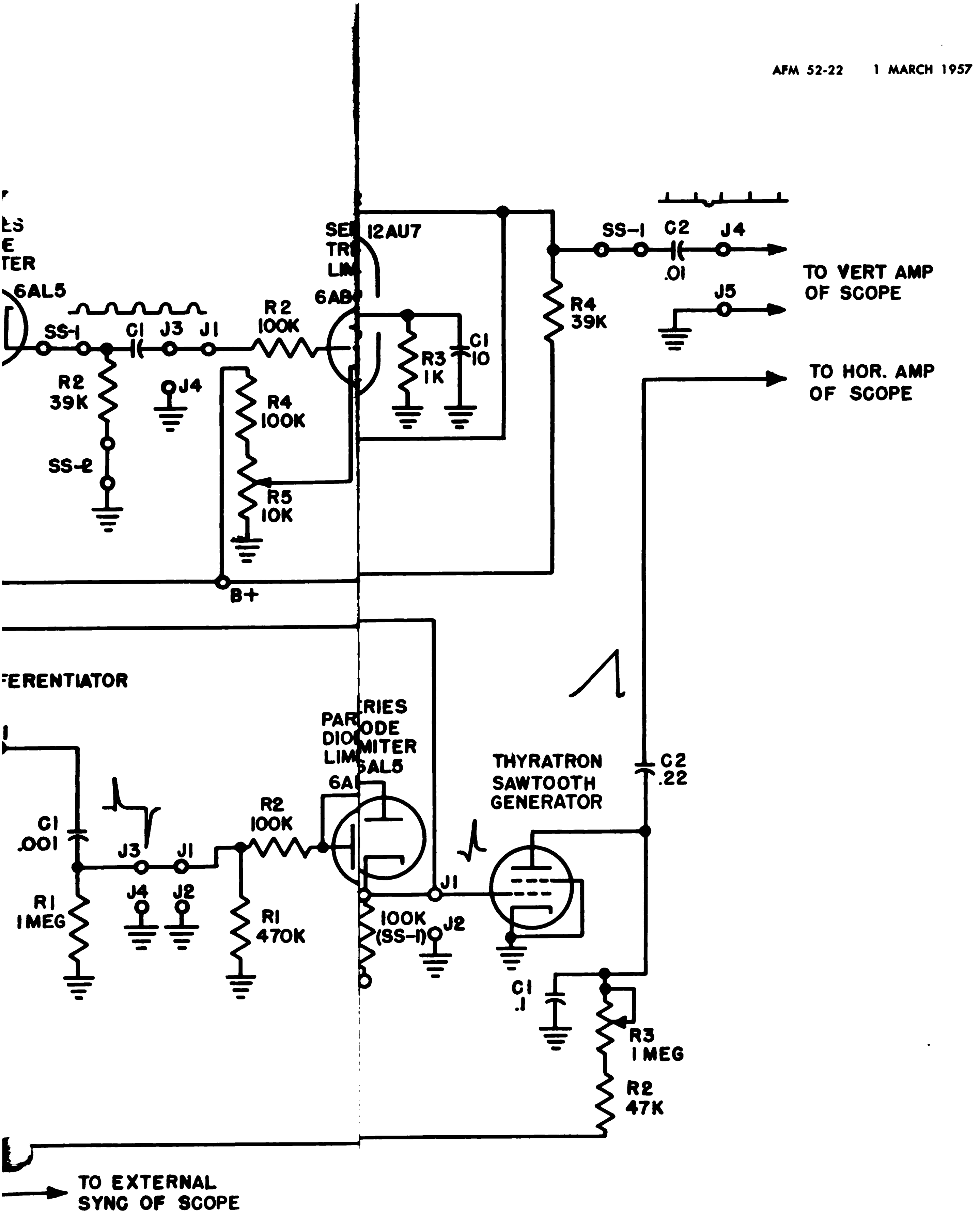
SECTION____

INDICATION (no output, distortion, etc.).

LOCALIZE TROUBLE TO A PARTICULAR SECTION OF THE EQUIPMENT.
(Describe method used.)

ISOLATE TROUBLE TO A PARTICULAR CIRCUIT.
(Describe method used.)

LOCATE TROUBLE IN A PARTICULAR FAULTY PART.
(Describe method used.)



Trouble-Shooting Diagram for Advanced Radar System
(Waveforms are taken from output of each stage.)

STUDENT TROUBLE-SHOOTING CHART

(To be designed by student.)

TROUBLE-SHOOTING PROCEDURE FOR ADVANCED RADAR SYSTEM (Continued)

TROUBLE-SHOOTING PROCEDURE FOR ADVANCED RADAR SYSTEM (Continued)

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